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SEED SETTING IN ALFALFA II[1]

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This paper is the second in a series dealing with factors affecting the production of alfalfa seed. The various phases of work included in this report are:

1. The effect of artificial tripping.
2. The effect of mechanical tripping.
3. The effect of mutilation of flowers on seed setting.

REVIEW OF PREVIOUS WORK

A more complete literature review will be found in the first paper of this series.(1)

Tysdal (2) concluded that ordinarily there is not sufficient automatic tripping to produce satisfactory seed crops, and that Megachile and Nomia bees are highly important tripping and pollinating agents. He also found that mechanical tripping does not appear feasible for two reasons: (1) Alfalfa is indeterminate in its habit; therefore to trip a large proportion of the flowers at the right time would necessitate going over the field many times; (2) Unless a machine were so constructed that it promoted a large amount of crossing, the self-fertilization resulting from such tripping would cause less seed per flower and lower vigour of growth of the resulting progeny than would result if the same flower were cross-pollinated.

THE EFFECT OF ARTIFICIAL TRIPPING

As reported in the previous paper by Lejeune and Olson (1), four treatments were applied to determine the effect of tripping individual flowers by hand. The four treatments were repeated in 1940 and were as follows:

1. Plants caged, not artificially tripped.
2. Plants caged, flowers tripped.
3. Plants not caged, not tripped.
4. Plants not caged, flowers tripped.

Each of the above treatments was applied to 4 plants selected at random in a field of Macsel alfalfa. All racemes used were tagged and the number of flowers per raceme noted. The mature seed pods from tagged racemes were harvested and the number of pods per raceme and seeds per pod recorded. The tripping was done with a small pair of tweezers, the

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keel and standard being pressed together. The flowers so treated were presumably self-fertilized except in the occasional event that transfer of pollen by wind or insects took place soon after tripping. Where the plants were caged, the cages, constructed with fly screen, were banked with soil at the base so that insects, except very small ones, could not enter and bring about uncontrolled tripping.

TABLE 1.—EFFECT OF ARTIFICIAL TRIPPING

Treatment	No. flowers treated		Flowers forming pods		Pods forming seed		Flowers forming seed		Average No. seeds per pod	
	1939	1940	1939	1940	1939	1940	1939	1940	1939	1940
			%	%	%	%	%	%		
Caged Untripped	2008	8422	3.3	4.3	59.7	87.4	2.6	6.6	.77	1.54
Caged Tripped	3197	6579	28.0	34.2	85.2	71.6	47.7	69.9	1.80	1.66
Uncaged Untripped	2200	6454	7.4	11.5	87.6	91.7	15.1	28.2	2.00	2.46
Uncaged Tripped	2430	6088	32.7	42.44	83.3	93.2	50.0	75.6	1.50	1.78

In Table 1 artificial tripping data are presented for 1939 and 1940. It is evident that tripping, whether in or outside cages, increased podding and seed setting. The difference between tripped and untripped plants in the proportion of flowers forming seed was greatest in the case of the caged plants. This fact emphasizes the importance of tripping. The fact that the corresponding difference was less in the case of the uncaged plants was no doubt due to the incidence of natural tripping by insects in those not artificially tripped. A difference in favour of the uncaged-untripped when compared with the caged-untripped ones in the proportion of flowers forming pods (7.2 in 1940 and 4.1 in 1939) is pertinent evidence.

In the column "average number of seeds per pod" the highest figures are found in the case of the uncaged-untripped plants. This is true for both years. The explanation is doubtless to be found in the greater amount of cross-fertilization that was naturally provided for there. In the column for "percentage pods forming seed" the 1939 figures show the same trend, while the 1940 figures show a slight advantage for the uncaged-tripped. Obviously this determination is not as good a criterion, since a pod, even though it contained a single seed, would be included in the category "pods forming seed." Such a pod would not be good evidence of the beneficial effect of cross-fertilization.

In looking for evidence of the beneficial effect of cross-fertilization, or the complementary situation, namely, the deleterious effect of self-fertilization, there are offsetting factors that must be taken into account in interpreting the data. Artificial tripping which does not involve the transfer of pollen would be expected to induce self-fertilization. On that basis artificially tripped plants would be expected to show fewer seeds per pod and lower percentage of pods forming seed than those artificially tripped. On the other hand, plants not caged, which permitted access of the most effective pollen transferring agency, namely, insects, would be expected

to show a higher number of seeds per pod and percentage of pods forming seed than caged ones, whether artificially tripped or not, since even artificially tripped flowers might be visited by insects soon after such tripping. This would be especially true if pollinating insects were abundant.

THE EFFECT OF MECHANICAL TRIPPING

Since it was established that the more flowers tripped the greater the amount of seed set, attempts were made to artificially induce tripping in the field by the use of various devices. The devices used and their application are listed and described below. The alfalfa treated was grown in rows spaced 3 feet apart.

1. Harrow: a single section of upturned harrows was dragged down the row of alfalfa.
2. Wire: a section of page-wire fencing, 5 feet wide, was pulled over the plants.
3. Stone-boat: this device was pulled over a row of alfalfa plants.
4. Float: this implement was constructed from two pieces of 2 × 12 lumber and overlapped. It was pulled over the rows at right angles.
5. Post: a cedar fence post was pulled at a 45 degree angle down the rows treated.
6. Logging chain: the chain was dragged in a "U" shape over the rows treated.
7. Rotary tripper: a home-made device which straddled a row. It consisted of a revolving wooden drum on which were attached stiff bristle brushes.
8. Tramping: a horse was used to tramp the soil thoroughly on both sides of the treated rows, in an attempt to stunt the plants by making soil conditions less favourable.
9. Float: constructed as in 4, but dragged over the rows with a weight of 175 pounds on it.
10. Wire: a single strand of wire was dragged over the rows to be treated.
11. Rotary tripper: constructed as in 7, but with pegs on the revolving drum in place of the stiff brushes.

The treatments were first applied when the alfalfa was 80 to 90% in flower. The number of flowers tripped was determined by random sampling of 100 racemes after each treatment. A similar count was made in several untreated check rows and the comparison between treated and check rows provided information as to the effectiveness of the treatments.

In practically all cases the treatment increased the amount of tripping sharply. However, such tripping was not accompanied by increased set of seed. As a matter of fact the treatment reduced the amount of seed produced in the majority of instances. It may be presumed that the treatment caused enough damage to plants and flowers to more than offset the beneficial effects of tripping. Rather severe damage to the plants was apparent.

Since mechanical tripping had no clear cut beneficial effects under any of the treatments the data for each treatment are not presented. Table 2, however, gives the averages for all of the treatments with each

device used. In the case of most of the devices, as shown in the list of treatments, four different modifications of treatment were made, namely, 1, one way once; 2, one way weekly; 3, both ways once; 4, both ways weekly. These four treatments have been averaged for each device and are shown in the table. This will give a clear enough picture of the extent to which tripping was increased and seed yield reduced. In the case of some of the devices data appear for 1939 and 1940.

TABLE 2.—THE EFFECT OF MECHANICAL METHODS OF TRIPPING ON SEED SET IN ALFALFA 1939-40

Treatment	Seed yield lb. per acre		Flowers counted		Flowers tripped	
	1939	1940	1939	1940	1939	1940
	lb.	lb.	no.	no.	%	%
Harrow	34.45	22.46	2034	1381	34.07	13.81
Check		53.26		1946		2.05
Page Wire		45.94		1494		8.06
Check		45.27		2004		.84
Float	57.16	28.63	2640	1595	56.09	8.02
Check		48.18		1923		.57
Stone-boat		24.63		1242		12.72
Check		42.61		1990		.95
Post	49.49	38.61	3028	1188	35.70	10.48
Check		29.29		1997		2.65
Logging Chain		35.28		1268		11.03
Check		55.93		1955		2.51
Rotary Tripper	68.98	45.27	1021	1210	39.46	5.52
Check		77.48		1788		1.90
Tramping		42.61		513		3.70
Check		53.26		665		5.26
Float with 175 lb. on it	32.64		1274		50.94	
Wire, single strand	61.66		2984		21.17	
Rotary Tripper with pegs in drum	68.98		1357		25.20	
Check (all 1939 treatments)	78.64		2325		26.62	

EFFECT OF FLOWER MUTILATION

To obtain some information regarding the effect of damage to individual flowers upon the amount of seed set and also the kind of damage that was most destructive, an experiment was performed in which the flowers were mutilated in various ways. The type of mutilation and the results are given in Table 3. The following are some of the more interesting comparisons.

TABLE 3.—EFFECT OF FLOWER MUTILATION ON SEED SETTING

Treatment	No. flowers treated	No. pods formed	No. seeds formed	Flowers forming pods	Pods forming seed	Aver. No. seeds per pod
				%	%	
1. Corolla and keel squeezed until tripping took place	853	341	374	40.0	96.2	1.09
2. Keel pinched until tripping took place	999	537	726	53.8	98.5	1.35
3. Entire standard cut off after tripping keel	99	16	28	16.2	75.00	1.75
4. Keel tripped then standard cut off above point of contact with stigma	382	165	240	43.2	97.6	1.45
5. Keel tripped then standard cut off below point of contact with stigma	229	65	104	28.4	86.10	1.60
6. Keel tripped then keel removed	191	125	157	65.4	99.20	1.25
7. Flowers tripped then raceme squeezed severely between fingers	212	28	29	13.2	60.7	1.03
8. Keel tripped after standard removed	306	27	44	8.8	37.00	1.62
9. Check for 8. Keel tripped standard not removed	556	188	277	33.8	98.40	1.20
10. Flowers naturally wilted without tripping	91	1	1	1.1	100.00	1.00

The check (item 9) where tripping was achieved with no damage or at least a minimum damage to any part of the flower, resulted in 33.8% of the treated flowers forming pods. Other treatments that were equally effective or more so were, item 1, corolla squeezed until tripping took place (40.0%); item 2, keel pinched until tripping took place (53.8%); item 4, keel tripped followed by cutting off standard above point of contact (43.2%); item 6, keel tripped followed by removal of keel (65.4%). The percentage of flowers forming seed under these treatments did not differ significantly. The treatments that, on the other hand, appeared to reduce the amount of seed setting were item 8, keel tripped after standard removed (8.8%); item 7, tripping followed by severe squeezing of raceme (13.2%) (contrast with item 1); item 3, entire standard removed after tripping keel (16.2%); item 5, keel tripped followed immediately by cutting off standard below point of contact with stigma (28.4%). This is an interesting contrast with item 4, where the standard was cut off above the point of contact with the stigma. The reduction in pod formation under the mutilation treatments just described (items 8, 3, 7 and 5) is accompanied in every case by reduction in proportion of pods forming seed.

SUMMARY

1. Artificial tripping of individual flowers increased sharply the amount of seed set.

2. Uncaged-untripped plants showed the highest number of seeds per pod of all treatments. This was no doubt due to increased amount of cross-fertilization caused by insect visitation.

3. A number of mechanical devices used in an effort to induce tripping on a large scale and thereby increase seed setting met with little success. Although the number of flowers tripped was increased in nearly all cases, the amount of seed set was less than in the untreated checks due, undoubtedly, to damage of the plants and flowers by the treatment. Rather severe damage to the plants was apparent.

4. Mutilation of individual flowers appeared to have a marked effect on seed setting. Treatments that reduced the amount of seed set more or less sharply were removal of the standard before or immediately after tripping, cutting off the standard below the point of contact with the stigma, and severe squeezing of the racemes.

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THE ADVANTAGES OF A SOIL PASTE FOR ROUTINE pH DETERMINATION[1]

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The determination of the hydrogen ion concentration of a soil sample is now considered one of the regular determinations in soil analysis. While this determination has been the subject of numerous investigations, there is still considerable diversity in the methods followed, especially in regard to the soil-water ratio (5).

The recent development of the glass electrode of the spear or penetration type has aroused new interest in the subject of soil acidity for it permits the making of pH determinations at moisture contents similar to those under which plant growth takes place. The use of this instrument has also directed attention to the fact that a soil may show considerable variation in pH when the soil-water ratio is changed.

McGeorge (2) has shown very clearly the effect of dilution on the pH of soils and pointed out wherein determinations made at high dilutions, especially in calcareous soils, may lead to erroneous conclusions. Huberty and Haas (1) also stressed the change in pH on dilution of calcareous soils. They found that in all the soils studied except one, the pH of the soil at field moisture content was less than at a soil-water ratio of 1 : 5. Puri and Asghar (4) state that, in the absence of water soluble salts, the pH is not affected by the soil-water ratio. They suggest the use of a *N* KCl solution instead of distilled water for obtaining uniform results, but also mention that soils containing calcium carbonate show higher pH values on dilution with H_2O or *N* KCl.

The determination of the pH value of soils at moisture contents similar to those found in the field is of particular value in studying the actual conditions under which plant growth takes place. This represents a moisture range from the wilting point to the moisture equivalent. The moisture equivalent, which is approximately the field capacity, represents the maximum amount of moisture held by a soil under field conditions. This would seem a logical moisture basis for the determination of the pH values of soils containing water soluble salts or calcareous material, for it would give the maximum hydroxyl ion concentration to which the plant roots would be subjected. However, for routine work, the determination of the moisture equivalent of every sample before determining the pH would require considerable time. Data will be presented to show the change in pH value on dilution of soils from southwestern Saskatchewan, and an outline given for routine pH measurement that does not require the weighing of the sample or measuring of the H_2O used.

The soils used in this experiment are representative of the brown soils of southwestern Saskatchewan. They have been formed from glacial till, are low in organic matter, and have a lime layer within 8 to 20 inches of the surface.

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EXPERIMENTAL METHODS

The soils were air dried and pulverized sufficiently to pass a 2 mm. sieve. All pH measurements were made with a standard pH meter using external electrodes with 30 inch cables, thus permitting the use of fairly large samples. The soil samples were placed in 100 ml. beakers, the desired amount of distilled H_2O added and well mixed with a glass rod. The pH readings were made 10 to 20 minutes after the H_2O was added.

RESULTS

Data are presented in Table 1 showing the variation in pH caused by increasing the moisture content from the moisture equivalent (determined by use of a centrifuge) to a soil-water ratio of 1 : 5. In all cases there was an increase in pH at the higher moisture contents. The same effect has been observed in many other soils checked at this laboratory. Soils 1237, 1294, 1295, and 1296 contain appreciable quantities of calcium carbonate

Table 1.—The effect of the soil-water ratio on the pH of prairie soils

Soil number	Soil-water ratio						
	Moisture equivalent	Paste	1 : 1	1 : 2	1 : 3	1 : 4	1 : 5
	pH	pH	pH	pH	pH	pH	pH
1202	5.54	5.66	5.76	6.00	6.08	6.16	6.28
918	5.88	6.02	6.04	6.16	6.24	6.40	6.46
1177	5.90	6.06	6.34	6.58	6.70	6.76	6.86
1152	6.20	6.28	6.46	6.68	6.74	6.86	6.98
839	6.32	6.42	6.48	6.60	6.70	6.80	6.90
1294	7.48	7.76	7.98	8.12	8.24	8.28	8.32
1237	7.62	7.88	8.00	8.22	8.44	8.54	8.76
1295	7.78	8.14	8.36	8.54	8.66	8.76	8.86
958	7.84	7.98	8.04	8.22	8.36	8.40	8.44
1251	8.15	8.28	8.50	8.78	9.00	9.20	9.40
1296	8.30	8.48	8.56	8.80	8.96	9.00	9.08

and have a fairly alkaline reaction at a 1 : 5 dilution. Soils 958 and 1251 also have a high reaction at the 1 : 5 dilution, but do not effervesce on treatment with HCl. These soils contain 0.72 and 0.11% of water soluble salts.

It was found that when the dilution was sufficient to permit the settling out of the larger particles, 1 : 2 or more, the pH of the mud at the bottom of the beaker was lower than in the solution above the sediment. This necessitated the constant shaking of the beaker while the meter was being read to obtain consistent results. A similar effect has been observed when using a quinhydrone electrode.

The moisture content of the samples at the paste stage varied according to the texture of the soil. Sufficient water was added so that after stirring with a glass rod the mixture would assume a level surface when the beaker was tapped gently once or twice on the table. This was a fairly thin paste that required from 15 to 28 ml. of H_2O for 40 gm. of soil. The paste was thin enough to permit good contact with the electrodes and thick enough

TABLE 2.—VARIATIONS IN pH CAUSED BY SLIGHT CHANGE IN SOIL-WATER RATIO AT PASTE STAGE

40 gm. of soil used for each determination

Soil number	Moisture equivalent	A − 2 ml.	A − 1 ml.	Paste A ml.	A + 1 ml.	A + 2 ml.
	pH	pH	pH	pH	pH	pH
1202	5.54	5.62	5.64	5.64	5.70	5.66
918	5.88	5.98	5.98	5.98	6.02	6.02
1152	6.20	6.24	6.26	6.26	6.28	6.32
839	6.32	6.44	6.40	6.46	6.44	6.46
1237	7.62	7.88	7.88	7.88	7.88	7.98
1296	8.30	8.42	8.44	8.46	8.48	8.52

to prevent an appreciable settling out of the coarser particles while making the determination. Constant readings were easily obtained. A paste of this consistency is easily removed from the electrodes by a fine stream of water from a wash bottle. McGeorge (3) recommends the use of a somewhat thicker paste, which requires the pressing in and withdrawal of the electrodes several times to obtain a constant reading. With the thin paste the electrodes can be easily shifted without removal from the sample.

Data are presented in Table 2 showing the slight change in pH caused by a difference in the consistency of the paste. Samples of 40 gm. were weighed out and the amount of water required to give the desired consistency determined. This amount is listed as A ml. in Table 2. Additional samples were then made up containing 2 and 1 ml. less than and 1 and 2 ml. more than A. The data show little variation in pH for this range in moisture concentration which was sufficient to give an appreciable difference in the consistency of the paste. The pH of the samples at the moisture equivalent is included in Table 2, for comparison with the readings at the paste stage. The latter are only slightly higher and indicate fairly closely the pH of the soil under field conditions favourable to plant growth.

The data in Table 3 show the variation in pH when paste samples were prepared from the same soil by different technicians. Each man worked independently using an unknown amount of soil and water. The pH meter was operated by a fourth person. The results show that by

TABLE 3.—VARIATIONS IN pH OBTAINED WHEN THE PASTE SAMPLES WERE PREPARED BY DIFFERENT TECHNICIANS

Technician	Soil number							
	1	2	3	4	5	6	7	8
	pH	pH	pH	pH	pH	pH	pH	pH
A	5.94	6.22	6.39	7.20	7.66	7.72	7.93	8.00
B	5.93	6.28	6.38	7.22	7.67	7.73	7.94	8.01
C	5.94	6.24	6.39	7.20	7.68	7.70	7.96	7.98

establishing an arbitrary standard in regard to the consistency of paste, consistent readings may be obtained without the necessity of weighing the soil or measuring the water. This is a distinct advantage when pH determinations are being made on a large number of samples.

SUMMARY

Data are presented showing the variations in the pH value of soils caused by increasing the moisture content from the moisture equivalent to a soil-water ratio of 1 : 5.

The use of a thin soil paste is recommended for routine pH determination because:

(1) the pH value is fairly close to that found at the moisture equivalent;
(2) constant readings are easily obtained;
(3) the electrodes can be easily shifted without removal from the paste and are easily cleaned after removal;
(4) the rapid settling of soil particles is prevented;
(5) the weighing of the sample or measurement of the water used is not necessary.

The soil-water ratio used when making the determinations should be stated when reporting the pH value of soils.

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THE INFLUENCE OF SOME ENVIRONMENTAL FACTORS ON THE EXPRESSION OF THE SOLID STEM CHARACTER IN CERTAIN WHEAT VARIETIES[1]

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INTRODUCTION

A co-operative project between the Dominion Entomological Laboratory, Lethbridge, Alberta, and the Dominion Experimental Station, Swift Current, was initiated in 1932 with the objective of studying the resistance of wheat varieties to the attack of the western wheat stem sawfly (*Cephus cinctus* Nort.) and the development of agronomically desirable varieties having resistance to sawfly damage.

In the progress of this investigation Kemp (3) reported in 1934 that certain solid stemmed wheats were resistant to sawfly damage. The resistant sorts were all varieties of *Triticum vulgare* with the exception of one, Golden Ball, which was a variety of *T. durum*.

In a further study on this project Farstad (2) has compared the development of the sawfly larvae in Marquis wheat (a suitable host as judged by its general susceptibility) and in certain solid stemmed wheats (unsuitable hosts according to Kemp's results). It was found that the larvae developing in the solid stemmed wheats exhibited certain abnormalities as compared with larvae developing in Marquis. These results taken in conjunction with the results from certain field and cage experiments on actual damage sustained led to the conclusion that the solid stemmed wheats were decidedly more resistant than the hollow stemmed varieties such as Marquis. Nevertheless a much higher percentage of damage was suffered by the solid stemmed wheats in these tests than that reported by Kemp.

The difference in results obtained is attributed by Farstad to the fact that whereas in Kemp's observations the solid stemmed varieties were almost completely solid stemmed, in his own studies the amount of solidness varied markedly when the material was grown under different environmental conditions. His results showed that under conditions where the solid stem character is not expressed the resistance of these varieties was much reduced or lost.

The solid stemmed varieties of *T. vulgare* used by Farstad were completely hollow when grown in the greenhouse and partially hollow when grown in field cages. Golden Ball, the solid stemmed variety of *T. durum* that was used, remained solid stemmed under all conditions but its resistance was less when it was grown under the conditions that caused the vulgare types to become hollow. As to the conditions responsible for the variable expression of this character he states, as a result of his observations, that "Apparently there is a close relationship between high soil fertility, adequate soil moisture, high humidity and reduced sunlight and the reduction in pith tissue in the solid stemmed wheats."

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Results obtained by Kemp since 1934 and summarized by Platt and Kemp (5) in 1937 showed that the expression of the solid stem character varied from season to season in solid stemmed varieties of *T. vulgare* grown at Swift Current. An examination of the stems of 31 varieties in each of the four years 1933 to 1936 showed that 5% of the stems were hollow in 1933; 25% in 1934; 85% in 1935; and 77% in 1936. Not all varieties showed such extreme variation. The average percentage of hollow stems in the two varieties showing the least variation were for each of the four years, 0%, 3%, 34% and 18% respectively.

The importance of this phenomenon in relation to the problem of breeding sawfly-resistant wheats is obvious. For this reason investigations were undertaken in 1938 in an attempt to determine what differences in stem solidness might be expected with material grown under a wide range of conditions and what environmental factors might be responsible for any variations that might occur. The present paper summarizes the results that have been obtained to date.

VARIETIES STUDIED

Three varieties of wheat were used in these experiments. Two of these, S-615 and S-633, are solid stemmed varieties of *Triticum vulgare*. They were obtained by Mr. Kemp of this Station from Dr. O. Frankel, Lincoln College, Christchurch, New Zealand, who originally obtained them from Portugal. Nothing further is known by the author as to the origin of these wheats. The third variety was Golden Ball, a solid stemmed variety of *T. durum*. According to Clarke and Bayles (1), this variety was introduced into America from South Africa. All of these varieties have been shown by Kemp (3) and later by Farstad (2) to have considerable resistance to sawfly attack. All are being used in the breeding program at this Station in an attempt to transfer their solid stem, and consequently their sawfly resistance, to agronomically desirable varieties being grown in this area.

The stocks of S-615 and S-633 used in these experiments were first purified by growing selected individual plants in progeny rows. Lines that showed off-types or hollow stemmed plants were discarded. Progenies of bulked rows were grown in individual plots and, again, plots showing off-types or hollow stemmed plants were discarded. The remaining plots were bulked to form a seed source for these experiments.

Repeated attempts to improve the amount of solidness in S-615 by selecting solid stemmed plants from populations showing a low average amount of solidness have failed.

METHODS OF CLASSIFICATION

In all the experiments described in this paper the following method of classifying the material for stem solidness was used. The main culm of an individual plant was split from end to end and each internode classified as solid, semi-solid or hollow. A solid internode was one in which the stem cavity was completely filled with pith. A semi-solid internode had portions of the internode filled and others not, or had a clearly recognizable ring of pith around the inside of the stem wall with a cavity in the middle. A

hollow internode contained only minute amounts of pith, narrowly confined to the wall, as is the case in such common varieties as Marquis and Thatcher.

Culms with all internodes hollow were given an index value of 0 and those with all internodes solid a value of 5. Intermediate types were given index values of 1, 2, 3, or 4 according to the following plan. A value of 1 was given to plants having a trace of solidness; a value of 2 to those having one internode solid; a value of 3 to those having half the internodes solid; and a value of 4 to those with all but one internode solid. Semi-solid internodes were given values approximating half those assigned to solid internodes. Thus a stem with two internodes semi-solid was given a value of 2 and one with all internodes semi-solid a value of 3. Stems in which a portion of the internodes were solid and others semi-solid were classified on the same basis. For example, a stem containing four internodes, one of which was solid and two of which were semi-solid was considered to have two, or half, the internodes solid and was given a value of 3.

The index of solidness of any particular variety was the average of the indices given to the individual plants examined.

FIELD EXPERIMENTS

Experiments were started in 1938 to obtain information on the variation in stem solidness of varieties when grown in various locations.

In that year the 3 varieties S-615, S-633, and Golden Ball were grown at Swift Current and at 11 different Dominion Experimental Substations scattered throughout southwestern Saskatchewan. In 1939 the 2 varieties, S-615 and S-633 were grown on 14 substations, at the Dominion Experimental Stations at Scott, Lacombe, Indian Head, Brandon, Beaverlodge and Swift Current, and at the University of Alberta, Edmonton. In each of these years the varieties were grown in single rod row plots, triplicated. Fifty individual plants from each plot were examined and classified for stem solidness. In all cases border plants were discarded. In 1940, S-615 and S-633 were grown on 10 substations, at the Dominion Experimental Stations mentioned above, at the University of Alberta and in addition at the Dominion Experimental Station at Melfort. They were grown in duplicated, single rod row plots in this year. One replicate was grown in one part of the experimental area and the other in another. Twenty-five plants from each plot were examined and classified for solidness.

The variation in the number of substations used was caused by factors outside of this experiment. It was feasible to grow this material only at points where varietal tests were being conducted. These points changed somewhat from year to year. In a few instances the variations were due to material being abandoned on account of crop failure or grasshopper damage.

The lesser amount of material grown and examined at each point in 1940 was due to the necessity of using less labour on this project. Previous results had indicated that there were very slight differences attributable to replicates and that within a plot, the variation between plants was not great.

A summary of the data obtained is presented in Table 1. As the results obtained with S-615 were essentially similar to those obtained with S-633 only the average values for these varieties are presented.

TABLE 1.—INDICES OF STEM SOLIDNESS OF WHEAT VARIETIES GROWN AT VARIOUS STATIONS, 1938–1940

Station	Index of solidness					
	Av. S-615 and S-633					Golden Ball 1938
	1938	1939	1940	Av. 1939–40	Av. 1938–40	
Valjean	4.1	2.2	4.3	3.7	3.5	4.4
Swift Current	2.0	2.8	4.7	3.8	3.2	4.9
Riverhurst	3.3	2.8	3.4	3.1	3.2	4.8
Shaunavon	4.4	0.8	4.1	2.5	3.1	4.7
Tompkins	3.2	1.3	4.1	2.7	2.9	4.8
Tugaske	3.0	1.2	4.3	2.7	2.8	4.4
Carmichael	3.5	1.7	3.2	2.5	2.8	4.8
Gravelbourg	3.2	1.6	3.1	2.3	2.6	4.8
Kincaid	2.6	0.5	3.7	2.1	2.3	4.8
Beaverlodge	–	4.3	4.9	4.6	–	–
Limerick	–	1.6	4.1	2.9	–	–
Shackleton	–	1.0	4.0	2.5	–	–
Indian Head	–	0.5	3.7	2.1	–	–
Brandon	–	0.4	3.3	1.9	–	–
Scott	–	0.8	2.8	1.8	–	–
Edmonton	–	1.1	1.0	1.1	–	–
Lacombe	–	0.8	0.9	0.9	–	–
Canuck	2.2	0.8	–	–	–	4.8
Fox Valley	3.8	1.2	–	–	–	4.9
Parkbeg	3.2	2.6	–	–	–	4.7
Herbert	–	2.6	–	–	–	–
Melfort	–	–	2.8	–	–	–
Ave. 9 Stations	3.3	1.7	3.9			–
Av. 17 Stations	–	1.5	3.5			–

The striking results from these data may be enumerated as follows:—

(1) The amount of solidness varied markedly from Station to Station. For example, at Beaverlodge S-615 and S-633 were almost completely solid in both years whereas at Lacombe they were almost completely hollow in both years.

(2) The amount of solidness varied from year to year. S-615 and S-633 were, in general, much less solid in 1939 than they were in 1938 or 1940.

(3) There is a very pronounced interaction in the amount of solidness exhibited by S-615 and S-633 between Stations and years. Figure 1 shows the amount of solidness at each of 17 Stations in each of the years 1939 and 1940. An examination of this figure reveals clearly the relatively different response at many Stations in 1939 as compared with the response in 1940.

(4) Golden Ball reacted differently than the other two varieties being essentially solid stemmed at all points where it was grown. These results and evidence that will be presented from other experiments show

FIGURE 1

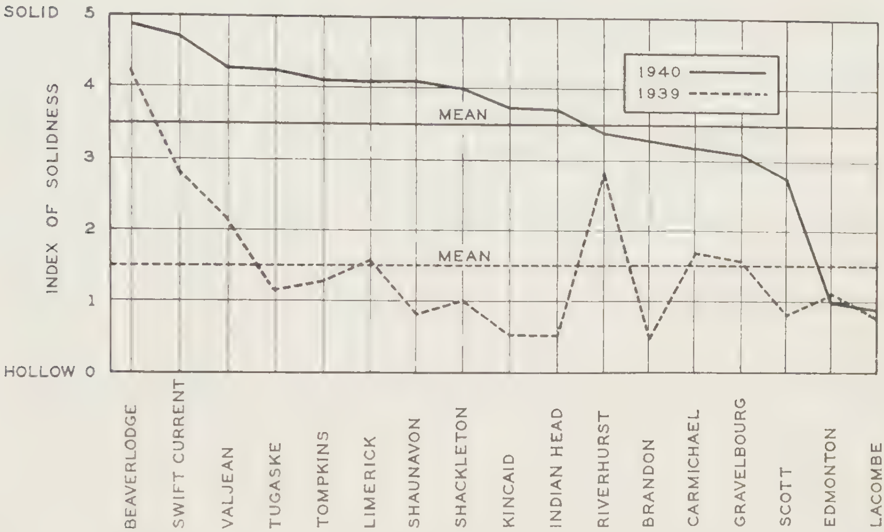

FIGURE 1. Mean indices of solidness of S-615 and S-633 when grown at various Stations in 1939 and 1940.

that the type of solidness possessed by this variety is not readily modified by environmental factors. For that reason it was dropped from these tests after the first year.

The factors responsible for the variations in the amount of solidness are, very probably, seasonal in nature rather than geographical. That is, they are most likely due to variations in rainfall, hours of sunshine, temperature or combinations of these than to soil type or geographical location. The variations between years and the interaction of Stations and years are evidence in support of such an hypothesis. The average index of solidness for the 10 most fertile[1] of the 17 Stations for which two years' results were available, was 2.4 units. The 7 less fertile Stations gave an average index of 2.8. This difference is not great compared with the difference between years or Stations. As the soil at most of these Stations was classified as loam no comparisons as to relative solidness on sand, loam and clay soil can be made. Nevertheless, the wide differences in amount of solidness between Stations, on soils of similar texture is evidence that texture exerts little or no influence.

In order to obtain information on the relation of seasonal factors to the expression of solidness, coefficients of correlation were calculated between the indices of solidness and hours of sunshine, inches of rainfall, and mean temperatures.

The index of solidness in each observation was the average of the individual indices of S-615 and S-633 for each year at each Station.

Data on all three seasonal factors together with indices of solidness were available for two years at each of the Stations Beaverlodge, Edmonton, Lacombe, Scott, Indian Head and Brandon. One year's results were

[1] Acknowledgment is made to Dr. J. L. Doughty, Officer in Charge, Dominion Soils Research Laboratory, Swift Current, who classified the soil types for relative fertility.

available from Melfort and seven year's results from Swift Current, making in all 20 observations. Temperature records were available for certain of the substations so that an additional 16 observations were possible, making in all 36 observations between temperature and solidness. Rainfall records were available at all points at which material was grown so that a total of 55 observations between rainfall and solidness were made.

A summary of the results obtained is presented in Table 2.

Table 2.—Coefficients of correlation between indices of stem solidness and hours of sunshine, mean temperatures and inches of rainfall

Time of Season	Coefficient of Correlation				
	N = 20			N = 36	N = 55
	S.Hs[1]	S.T[2]	S.R[3]	S.T	S.R
May	.2051	−.0636	−.3195	−.0859	−.8835*
June	.5030*	.1225	−.2132	.3250*	−.4918*
July	−.3094	−.2316	.1881	−.0593	.1668
May 1 – June 30	.4390	–	−.0438	–	−.6890
June 1 – July 31	.2002	–	−.0329	–	−.3780*
May 1 – July 31	.2635	–	−.2240	–	−.5513*
April 1 – July 31	–	–	−.2032	–	−.4508*
Aug. 1 – July 31	–	–	−.0562	–	−.4913*

[1] Indices of solidness and hours of sunshine.
[2] Indices of solidness and mean temperatures.
[3] Indices of solidness and inches of rainfall.
* P value less than 0.05.

A significant, positive correlation between hours of sunshine in June and indices of solidness was found. In all other cases involving only the 20 observations the coefficients of correlation were non-significant. Mean temperature in June was positively correlated with solidness when the 36 observations between these two variables were considered. When the 55 observations between rainfall and solidness were considered, significant, negative correlations were established between solidness and all rainfall combinations used except July rainfall.

Data from the 20 observations were used in the calculation of partial correlations among the four variables, namely: solidness, June sunshine, temperature and rainfall. These calculations failed to change materially the relationship between these variables as shown by the coefficients of correlation reported in Table 2.

The significant correlations between rainfall and solidness that were obtained from the 55 observations are in marked contrast to the non-significant values obtained from the 20 observations. In the smaller sample, 7 of the 20 observations were made in southwestern Saskatchewan whereas in the larger sample, 42 out of 55 observations were made in southwestern Saskatchewan. This would indicate that solidness and rainfall are more closely correlated in southwestern Saskatchewan than they are over Western Canada as a whole. This is probably due to the fact that the effect of a given rainfall on plant growth is more constant over a small area than over a large one.

The results as a whole show that the expression of the solid stem character is favoured when long hours of sunshine and high temperature prevail in June and when the rainfall throughout the growing season is low. The relative importance of these factors will be discussed in a later section of this paper in the light of results from these and other experiments.

That June is the critical month in determining the expression of the solid stem character is indicated by the above results. An examination of stems at periodic intervals throughout the growing season showed that most changes in solidness occurred during the period of stem elongation. This takes place very largely during June but may, in some cases, extend into July.

GREENHOUSE EXPERIMENTS

The relationship between the stem solidness of mature plants and the soil moisture conditions prevailing during their growth was studied in the following experiment conducted during the summer of 1938.

The two varieties S-615 and S-633 were sown in wooden flat boxes placed in the greenhouse and subjected to 19 different moisture treatments. Each treatment was in duplicate and there were 50 plants of each variety in each replicate of each treatment.

The moisture treatments are briefly described as follows: One series was given adequate moisture at all times, a second was given only sufficient to keep the plants alive and growing slowly, while a third was alternatively, at weekly intervals, given an adequate and an inadequate moisture supply. Eight of the remaining 16 series were grown for various periods under an adequate moisture supply and then, for the remainder of the growth period, one-half of each of these series was grown under an inadequate and one-half under an alternating inadequate and adequate supply. The other eight series were grown under an inadequate supply for various periods and then one-half under an adequate and one-half under an alternating supply.

At maturity the growth and productivity of the plants was found to be closely related to the amount of moisture they had received. Those grown with an adequate moisture supply were tall, productive, normal plants whereas those growing with an inadequate supply were earlier maturing, stunted and produced only a few seeds per spike. All gradations between these extremes were found in plants receiving the other treatments.

When the mature plants were examined it was found that they were all hollow stemmed regardless of treatment. It is evident that some other factor or series of factors operating in this experiment influenced the degree of solidness much more than the moisture treatments to which the plants were subjected.

Since that time a great many plants of these two varieties and of Golden Ball have been grown in the greenhouse in connection with breeding programs and invariably plants of S-615 and S-633 have been hollow or almost hollow stemmed. Generally well spaced plants of these varieties show a trace of solidness when grown in the summer months but no solidness when grown in the winter months. Golden Ball has been solid stemmed when grown during the summer months but has generally been only partially

solid when grown during the winter months. Evidently the environmental factor or factors responsible for the non-expression of the solid stem character are always operating under greenhouse conditions and are accentuated during the winter months.

SPACING EXPERIMENT

In 1939 it was observed that plants of S-615 grown in the field and seeded at the normal rate of 1.5 bushels per acre were less solid than nearby plants spaced 2.5 inches apart in rows one foot apart.

In order to check the effect of spacing on the expression of the solid stem character the following experiment was conducted in 1940. Seeds of S-615 were sown in 6 rod row plots at the following rates: a seed every 0.5, 1.0, 2.5, and 6.0 inches in rows 7 inches apart. The same rates were used in a second series in rows 14 inches apart. Each treatment was quadruplicated and arranged in randomized blocks. When the crop was mature 25 plants from the two centre rows of each plot were examined and classified for solidness.

A summary of the results obtained is presented in Table 3.

TABLE 3.—INDICES OF STEM SOLIDNESS OF PLANTS OF S-615 WHEN SPACED AT VARIOUS INTERVALS

Distance apart of seed in rows (inches)	Index of solidness	
	Rows 7 inches apart	Rows 14 inches apart
0.5	3.4	3.1
1.0	3.3	3.3
2.5	3.3	3.9
6.0	3.7	4.3

The minimum significant difference between any two indices is 0.4 units.

In the series grown in rows 14 inches apart, decreasing the rate of seeding within the row resulted in a greater expression of the solid stem character. However, the differences are not great. When the material was grown in 7-inch rows, plants spaced 6 inches apart were slightly more solid stemmed than those seeded more thickly. These results demonstrate that the expression of the solid stem character can be modified to some degree by increasing or decreasing the distance between plants.

General conditions in 1940 at Swift Current were favourable for the expression of the solid stem character according to the results from the standard tests reported in Table 1. It would be expected that under such conditions it would be more difficult to modify the expression of the solid stem character by such methods as spacing than it would be in a season that was less favourable for the expression of this character. It is thought that had general conditions been less favourable for the expression of solidness the differences in solidness, apparently due to differences in spacing, would have been greater.

SHADING EXPERIMENT

Information on the effect of variations in light intensity on the expression of the solid stem character was sought in the following experiment.

Duplicate square plots, 20 feet by 20 feet, were seeded to S-615 and Golden Ball in an area 40 feet by 40 feet. S-615 occupied the southwest and northeast portions of the seeded area and Golden Ball the southeast and northwest portions. As soon as the material was seeded a stand 4.5 feet high and 20 feet square was erected over the centre of the seeded area. The top of the stand was covered with cotton sheeting. This sheeting had been used on outside cages for some years and was worn very thin. The sides of the stand were not covered in order that air movement among the shaded plants would not be impeded. With this arrangement plants growing under the centre of the stand were shaded from the sun's rays throughout their growing period. Those growing to the south of the stand had no shading at all while the remainder had various combinations of shading and full light.

Fifty plants of each variety were collected in three different locations and examined for solidness. Sample 1 was taken from material grown to the south of the stand in full light. Sample 2 was taken from material grown at the south edge of the stand and was shaded in the early morning and late afternoon and in full sunlight during the remainder of the day. These plants were not distinguishable from those grown in full light in so far as outward appearances were concerned. Sample 3 was taken from under the centre of the stand and was shaded at all times during the growing period. This material was later in maturing, taller and weaker in the straw than the material grown in full light.

The indices of solidness of these samples were:—

	S-615	*Golden Ball*
Sample 1—Full light	3.8	5.0
Sample 2—Partial shade	0.0	4.9
Sample 3—Full shade	0.0	4.5

These results show very clearly that even moderate shading has a great influence on the expression of the solid stem character in S-615. Moderate shading had no appreciable effect and continuous shading only a slight effect on the solidness of Golden Ball.

DISCUSSION

The data that have been presented show that the expression of the solid stem character in the vulgare type solid stemmed wheats varied markedly under different environmental conditions. Under field conditions the expression of this character is affected by variations in light, temperature, moisture supply and spacing, and its expression is almost completely inhibited under greenhouse conditions.

The results from the experiments as a whole suggest that light is the most important factor limiting the expression of this character. The almost complete inhibition of solidness brought about by shading, shows that light alone can greatly influence the amount of solidness that occurs. The lack

of solidness in stems of material grown in the greenhouse is thought to be due to the lower light intensities experienced under greenhouse conditions. The fact that it was not possible to alter the expression of solidness under these conditions by varying the moisture content over wide limits is evidence that light rather than moisture was the limiting factor. Further evidence for this hypothesis comes from the reaction of Golden Ball in the greenhouse. It has always been solid when grown in the summer but has shown some hollowness when grown in the winter during which time the light intensity is lower. The results from the spacing experiments are also significant. Widely spaced plants differ from those closely spaced in that they have a greater moisture supply and are more exposed to the sun's rays. If it is assumed that moisture is the factor involved it is evident that solidness and moisture supply are positively correlated as the widely spaced plants were the most solid. All other field results show that solidness and moisture supply are negatively correlated hence it seems more logical to assume that light rather than moisture is the factor of primary importance in this experiment. Field experiments showed a positive correlation between hours of sunshine and solidness and temperature and solidness, and a negative correlation between rainfall and solidness. It is practically impossible in uncontrolled experiments to separate out the individual effects of light, temperature, and rainfall because of the intercorrelations between these variables. In these experiments solidness was favoured by long hours of sunshine, high temperatures and scanty rainfall. Heavier rainfall, that would produce greater foliage growth and hence inhibit the penetration of light, favoured hollowness. There is, therefore, nothing in these results that is contrary to the hypothesis that light is the primary factor in determining the presence or absence of solidness. The somewhat low value obtained for the correlation between hours of sunshine and solidness is probably due to the fact that hours of sunshine for June is a very crude measure of the light intensity at the stems of wheat plants during the period of elongation.

Somewhat similar cases of the effect of light on plants have been reported. Maximov (4) points out the well known differences in the structure of sun and shade leaves. In the former the palisade layer is much more highly developed, the amount of spongy tissue is less and the inter-cellular spaces are smaller. Shading has been found by many investigators to result in a reduction in the dry matter content of the stem and to predispose the plants to lodging. In this regard Welton and Morris (7) found that soybeans grown with and shaded by corn, or when shaded artificially, were weak stemmed and prone to lodge. Shaded plants contained less total carbohydrates than those grown in the open. Under reduced light it is possible that the pith in solid stemmed wheats would consist of loosely associated cells with thin walls while under greater light intensity the pith would consist of more closely packed cells with thicker walls. The former type would be expected to disintegrate much more rapidly.

In all the experiments in which they were compared the expression of the solid stem character in the durum variety, Golden Ball, proved to be less susceptible to environmental influences than that of the vulgare

types, S-615 and S-633. Golden Ball would, therefore, tend to be more consistently resistant to sawfly attack even though the actual resistance of this variety does vary under different environmental conditions as has been shown by Farstad (2). The incorporation of the Golden Ball type of solidness into agronomically desirable vulgare types of wheat involves the difficulties of interspecific hybridization. Whether or not this character can be successfully transferred awaits the results of breeding work now under way at this Station.

There appeared to be undue difficulty in producing hybrids having the solid stem of S-615 or S-633 and the desirable characteristics of varieties now being grown according to the results of Platt, Darroch and Kemp (6). Such hybrids, however, may be expected to show the same variability in the expression of the solid stem character as do the parents.

How greatly such variations in solidness can be expected to affect the usefulness of a solid stemmed wheat, in sawfly control, cannot be stated with certainty from the information available. A wheat having the solid stem characteristics of S-615 or S-633 in a given district can be expected to exhibit high resistance in some years, practically no resistance in other years and intermediate amounts in still others depending upon the seasonal conditions prevailing. The level of the sawfly population depends to a large extent on their survival from the preceding crop. If a solid stemmed wheat was grown exclusively over a whole district the cumulative effect of even occasional years of high resistance probably would be of great practical importance. In this regard Criddle reported by Farstad (2) found in certain sections of Manitoba that the continuous growing of durum wheat reduced sawfly damage from severe to insignificant. The resistance was not immediate but appeared to be cumulative, since durum following Marquis may be severely damaged. In order to notice any marked reduction in injury this wheat had to be grown for two or more years.

It would seem likely that the solid stemmed wheats would give similar results and over a period of years would substantially reduce damage from sawfly attack.

SUMMARY

Certain solid stemmed varieties of *Triticum vulgare* and *T. durum* are resistant to the western wheat stem sawfly (*Cephus cinctus* Nort.). Under environmental conditions that inhibit the expression of the solid stem character these varieties exhibit little or no resistance. The present study is concerned with the effect of various environmental factors on the expression of this character.

Two solid stemmed varieties of *T. vulgare*, S-615 and S-633 were grown at various points throughout southwestern Saskatchewan in the years 1938–1940 and at 7 Stations scattered throughout the prairie provinces in 1939-40. The degree of solidness exhibited by these varieties was found to vary from year to year and from Station to Station. Data on hours of sunshine were available for 20, on temperature for 36, and on rainfall for 55 Station years. In the former, 7 of the 20 and in the latter, 42 of the 55 observations were made in southwestern Saskatchewan. Hours of sunshine in June were positively correlated with solidness. Mean temperature

in June was positively correlated with solidness when the 36 observations were considered but the correlation was not significant on the basis of the 20 observations. Rainfall for the crop year, seasonal rainfall, May rainfall, and June rainfall were all negatively correlated with solidness on the basis of the 55 observations, but none were significant when only the 20 observations were considered.

Golden Ball, a variety of *T. durum*, was found to be essentially solid stemmed when grown at 14 Stations for one year.

The varieties S-615 and S-633 were found to be hollow stemmed when grown in the greenhouse where it is known that light intensity is lower than it is in the field. Varying the moisture supply over wide limits did not alter the expression of solidness under these conditions. Golden Ball was solid stemmed when grown during the summer but showed some hollowness when grown during the winter in the greenhouse.

Widely spaced plants of S-615, grown in the field, were more solid than closely spaced plants.

Artificial shading inhibited the expression of solidness in plants of S-615 but had comparatively little effect on plants of Golden Ball.

On the basis of the experiments conducted it is concluded that the type of solidness found in Golden Ball is not readily modified by environmental factors but that possessed by S-615 and S-633 may be profoundly modified by such factors. Variation in light intensity is considered to be the chief factor responsible for variations in the expression of the solid stem character in these latter varieties.

The variations in the expression of solidness noted in these vulgare varieties may be expected to result in variable resistance to sawfly attack. It is thought that such varieties could still be expected, over a period of years, to exhibit sufficient resistance to reduce, substantially, damage from sawfly attack.

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THE PREDOMINANCE OF RACE 56 IN RELATION TO THE STEM-RUST RESISTANCE OF CERES WHEAT[1]

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It is generally believed that the wheat variety Ceres, produced from a cross made by L. R. Waldron in 1918 and distributed in 1926, was at least moderately resistant to stem rust until 1935. In that year and in certain subsequent years it suffered severe damage from stem rust. Stakman (2) and Stakman and Cassell (3) have suggested that the rust reaction of Ceres changed as a result of the prevalence of race 56, which was first discovered in 1928, and which has, since about 1934, been the predominant race of wheat stem rust in the Great Plains region.

Owing to the possibility that, in years to come, Ceres may be cited as an outstanding example of a variety that lost its resistance as the result of the coming into prominence of a new pathogenic race, it seems desirable to present what information is available in Canada concerning its resistance and the effect on it of the rise to prominence of race 56. Two principal questions are involved, namely: (1) Was Ceres more resistant before than after 1935 and (2) Is Ceres less resistant to race 56 than to such races as 21, 34, 36, 38 and 49, which were the most prevalent races prior to 1935?

FIELD OBSERVATIONS

An attempt was made to answer the first question by examining available records of stem-rust infection and yield of Ceres from the time of its introduction to Canada. Long-term records for amounts of rust on Ceres were available only for three places, namely, Morden, Brandon, and Winnipeg. These records show (Table 1) that at Morden and Brandon, where only natural rust infestation was present, Ceres bore considerably more rust in the period 1934-1938 than in the earlier period 1924-1933.

TABLE 1.—PERCENTAGE OF STEM RUST ON CERES AND MARQUIS FOR THE PERIOD 1924-1933 WHEN RACE 56 WAS ABSENT OR RARE, AND FOR THE PERIOD 1934-1938 WHEN IT WAS THE PREDOMINANT RACE

Period	Natural rust infestation				Natural + artificial rust infestation	
	Morden		Brandon		Winnipeg	
	Ceres	Marquis	Ceres	Marquis	Ceres	Marquis
1924-1933	16	40	16	45	69*	82*
1934-1938	47	53	45	55	65	76

* From 1926 to 1932 only.

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A comparison of the amounts of stem rust on Ceres and Marquis for the same two periods (Table 1) makes it clear that at Morden and Brandon the percentage of rust on Ceres approximated that on Marquis more closely for the later than for the earlier period. At Winnipeg where, in the rust nursery, the natural rust epiphytotic was supplemented by artificially-produced rust infestation comprising many physiologic races, the relative amounts of rust on the two varieties were about the same for both periods. It is clear, therefore, that, given early infection, Ceres could become very heavily rusted by the physiologic races that were prevalent before race 56 became common. Concerning the higher percentages of stem-rust infection on Ceres and Marquis from 1934 onward, it should be mentioned that, in 3 of the 5 years involved, severe outbreaks of stem rust occurred in Manitoba, while in the preceding 10-year period stem rust was severe in only 3 or 4 years, and, in these, the stem-rust attack developed comparatively late.

Data on yields show that, when subject to natural rust infestation, Ceres did not suffer appreciable damage in Manitoba until 1935. That it could suffer damage from physiologic races prevalent in earlier years is shown by the yields at Winnipeg in 1930 under conditions of naturally and artificially produced stem-rust infection. In rod-row tests, its yield was only 7.8 bushels as against 19.1 bushels for the highly resistant variety Hope. Ceres, however, did not suffer as much as Marquis, which yielded only 3.9 bushels. Undoubtedly the early outbreak of stem-rust infection (early in relation to the stage of crop development) in 1935 and 1938 was a factor contributing to the higher percentage of infection and to reduced yields in these two years.

In conclusion, it may perhaps be doubted whether the high reputation for rust resistance enjoyed by Ceres prior to 1935 was altogether justified. It appears nevertheless to be true that Ceres rusted more lightly before that year than has frequently been the case since.

EXPERIMENTAL RESULTS

The second question stated above, that is, the relative virulence on Ceres of race 56 and other races prevalent before 1935, has been studied experimentally in the greenhouse and in the field. In these experiments, a comparison was made of the reaction of Ceres to race 56 with its reaction to races 19, 21, 34, 36, 38, and 49, which formed the bulk of the stem-rust isolates from 1925 to 1933.

All the infection experiments were conducted with plants in the heading stage. Three greenhouse experiments conducted in May, July, and November, 1938, were supplemented by two field experiments, one carried out in the summer of 1939, the other in the summer of 1940.

Greenhouse Experiments

In the greenhouse experiments, each lot of plants was inoculated with a single race only, the urediospores being applied to the leaves and stems with the fingers, after which the plants were placed in damp chambers for 24 hours. All inoculations in each experiment were performed at the same time. The infection results were recorded leaf by leaf and internode by internode. To permit a ready comparison of the resistance of the variety to the different races, numerical values were given to the infection types

recorded, by means of a modification of the scale invented by Goulden, Newton and Brown (1). In the modified scale, the numerical value 5 was given to the infection type "1", 10 to type "2", 15 to type "3", and 20 to type "4."

A preliminary infection experiment conducted in May 1938 with races 56, 21, 36, 34, and 38 indicated that Ceres was moderately susceptible to races 56, 21, and 36, moderately resistant to race 34, and resistant to race 38. The virulence of the first three races appeared to be in the order given, but the differences were slight.

The results of later greenhouse tests, conducted in July and November of the same year, are summarized in Table 2. In the first test, Ceres proved slightly more susceptible to race 56 than to any of the other races. In the second test races 36 and 56 appeared to possess about the same degree of virulence. The other races included in this test proved decidedly less pathogenic.

Table 2.—Reaction of Ceres wheat to several physiologic races of wheat stem rust in greenhouse experiments conducted in July and November 1938

Race	No. culms tested	Numerical values for infection types								Reaction
		Neck	Top sheath	2nd sheath	3rd sheath	4th sheath	Flag leaf	2nd leaf	Mean	
		July 1938								
56	14	19.0	16.5	14.2	12.9	7.0	11.4	10.9	13.1	MS
21	9	15.1	13.5	11.8	9.4	5.7	11.3	10.9	11.1	MR
34	8	13.7	11.6	10.3	8.9	9.0	11.2	10.2	10.7	MR
36	9	14.7	12.4	10.9	6.9	5.5	9.8	9.3	9.9	MR
113	6	14.2	11.0	9.1	5.0	5.0	9.7	8.4	8.9	MR
38	6	14.5	9.9	7.2	7.7	4.0	8.2	7.6	8.4	MR
		November 1938								
36	12	17.7	18.9	17.0	16.8	—	16.2	15.4	17.0	S
56	11	17.5	18.6	15.9	15.0	—	17.1	17.2	16.9	S
49	13	16.0	14.9	13.5	11.9	—	14.3	14.0	14.1	MS
21	13	14.7	14.3	13.7	13.7	—	14.8	13.0	14.0	MS
19	13	—	12.4	11.3	11.3	—	11.8	13.4	12.0	MR
38	14	12.4	9.9	8.9	4.7	—	9.0	9.0	9.0	MR

Note: 0 to 2.5 = I (immune); 2.6 to 7.5 = R (resistant); 7.6 to 12.5 = MR (moderately resistant; 12.6 to 15.5 = MS (moderately susceptible); 15.6 to 22 = S (susceptible).

Field Experiments

Although the data derived from the greenhouse experiments indicated that race 56 does attack Ceres more severely than several other races that have been widely prevalent in North America, it was felt that any conclusive proof of the greater virulence of race 56 must come from field experiments. A field experiment was therefore planned in the spring of 1939. Ceres wheat was sown in small plots (5 × 5 feet) separated by buffer plots of oats. At the commencement of heading, on June 28, urediospores of races 21, 36, 38, 49, and 56 were dusted on the plants, one race to each plot. Sixteen days later, when the pustules were well developed, notes were taken on infections on the two uppermost leaves and sheaths of 20 plants selected at random in each plot. The results of this experiment are summarized in Table 3.

TABLE 3.—REACTION OF CERES TO FIVE PHYSIOLOGIC RACES IN A FIELD EXPERIMENT IN 1939

Race	Numerical values for infection types					Reaction
	Top sheath	2nd sheath	Flag leaf	2nd leaf	Mean	
56	19.2	18.2	13.7	10.4	15.4	MS
49	17.5	16.7	12.9	10.4	14.4	MS
36	18.0	16.2	11.7	9.7	13.9	MS
21	16.8	15.4	11.8	10.1	13.5	MS
38	10.4	9.8	7.6	6.4	8.6	MR

The experiment was repeated in the summer of 1940. The procedure was the same as in the previous experiment except that three randomized plots were inoculated with each race instead of one, and that race 15 was substituted for race 49. The infection results are summarized in Table 4.

TABLE 4.—REACTION OF CERES TO FIVE PHYSIOLOGIC RACES IN A FIELD EXPERIMENT IN 1940

Race	Plot no.	Percentage rust	Numerical values for infection types					Reaction
			Top sheath	2nd sheath	Flag leaf	2nd leaf	Mean	
56	3	85	20.0	18.7	15.4	14.8	17.2	
	6	90	20.4	18.7	15.5	14.2	17.2	S
	14	85	20.4	18.4	14.8	13.5	16.8	
36	5	35	19.0	15.4	14.7	12.9	15.5	
	8	75	18.4	16.3	14.1	13.4	15.6	MS
	11	70	18.7	15.9	14.2	13.0	15.5	
21	2	50	15.3	13.1	14.3	12.4	13.8	
	10	55	17.1	14.9	14.7	12.6	14.8	MS
	12	55	17.1	15.1	14.6	12.3	14.8	
15	4	45	15.7	14.1	13.5	11.1	13.6	
	7	50	15.0	14.3	13.4	11.3	13.5	MS
	13	45	14.4	12.7	11.7	10.1	12.2	
38	1	55	10.9	6.9	8.7	6.6	8.3	
	9	50	11.8	8.5	9.8	6.6	9.2	MR
	15	40	11.8	7.4	8.4	6.3	8.5	

A comparison of Tables 3 and 4 will show that, in both experiments, race 56 appeared to be more virulent on Ceres than the other races. It should be noted, too, that the three other races common to the two experiments, namely, races 36, 21, and 38 fell into the same order of virulence in both experiments. Attention should also be called to the fact that, in the 1940 experiment, the percentage readings for rust on the three plots infected with race 56 were distinctly higher than on plots infected with the other races. This is perhaps, in part, the result of the larger size of the rust

pustules formed by race 56. It is noteworthy that the order of virulence of the first four races, i.e. races 56, 36, 21 and 15, is the same whether judged by infection types or by percentage of rust infection.

CONCLUSIONS

Consideration of these data leads to the conclusion that race 56 is somewhat more pathogenic on Ceres than races 21, 34, 36, 38, and 49, which were the chief components of stem-rust epiphytotics in Western Canada during the years when Ceres rarely suffered noticeable damage from stem rust. It can scarcely be doubted that the predominance of race 56 in 1935 and in subsequent years is one of the factors responsible for the severer rusting of Ceres in recent years.

Whatever the rôle played by race 56 in the apparently increased susceptibility that Ceres has shown in the last few years, it must not be assumed that the disappearance of Ceres as an economically important wheat is solely the result of the predominance of this race. The coming into prominence of race 56 coincided with the production of wheat varieties with much greater stem-rust resistance than Ceres ever possessed, and it was the existence of such varieties that made its disappearance inevitable.

It is probable that factors other than the presence of race 56 have played a part in the severe rust damage that Ceres suffered in 1935 and in later years. It is likely that in 1935, when it was attacked more severely than ever before or since, the early arrival of stem-rust inoculum combined with a rather late but very succulent crop growth resulted in a more destructive attack than any that Ceres had ever experienced before. What the effect would have been if race 56 had been absent is impossible to say. It is noteworthy, however, that Mindum wheat, a moderately resistant *durum* variety, which is not attacked by race 56, was very severely damaged in many localities in that year. It may well be that, in years before race 56 became predominant, Ceres was never subjected to as severe a test as it received in 1935 and 1938. Although 1925, 1927, and 1930 were years of rather heavy rust infestation, the losses caused to susceptible wheat varieties, such as Marquis, were not as great as in 1935.

The fact, already mentioned, that Ceres was severely damaged in the rust nursery at Winnipeg in 1930 when race 56, if present at all, constituted only a minute fraction of the rust, shows that, under appropriate conditions, other races are capable of damaging it. In spite of the damage caused in this instance, it would appear that there was a marked difference in the rust reaction of Ceres in the field before and after 1935 which can be accounted for, at least in part, by the prevalence of race 56. This appears to be an instance of the impairment of the productive value of a widely grown wheat variety by the ascendancy of a new physiologic race of stem rust, a conclusion suggesting the possibility of similar occurrences in the future.

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REMOVAL OF MOISTURE FROM HONEY[1]

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Moisture in honey has been the subject of much experimental work during recent years. This work has been directed largely towards estimating the quantity of moisture in the honey, how it can be measured, and its relationship to resulting physical and biological conditions. Because of such studies the conception of the amount of moisture in honey has changed, rapid methods of measuring moisture content have been devised, and it has become possible to extend experimental work to determine the moisture content of honey in the cells of a comb.

CHANGING CONCEPTION REGARDING MOISTURE CONTENT

Earlier methods for determining the moisture content of honey gave results indicating that average honey contained approximately 20% of water. It is reported (20) that a sample of genuine honey supplied by R. F. Holterman, Brantford, Ont., contained 27.1% of water, and 14% of presumably genuine samples of honey analysed by the Department of Inland Revenue for Canada contained 25% or more of water. The highest amount was 31.4%.

Shutt (17) believed that these results were much too high and standardized a method of obtaining what he believed to be more nearly the correct amount of moisture.

Drying methods (25) such as standardized by Shutt (18) were used in practically all official analyses for moisture content of honey prior to the development of tables for use with the refractometer (3). In 1910 the Department of Inland Revenue (21) reported 132 samples of honey of Canadian origin with an average moisture content of 22.7%, the range being 17.4 to 28.4%. The report of 1914 (22) gave a range of 7.33 to 24.90% of moisture with an average content of 15.9% for 164 samples of Canadian honey.

It is probable that some of these results are erroneous, as variations in the technique used by different workers might give misleading results. In the earlier reported work such was admitted.

We might attribute our changed conception of the correct moisture content of honey to the fact that the drying methods gave misleading results, if it were not that other methods were used also. Two of these were the weight per gallon and the determination of specific gravity by the hydrometer.

Corneil (5) stated that a specific gravity of 1.370 determined by the hydrometer, or about 13¾ pounds to the Imperial gallon, was considered by best authorities to be about right. This standard would mean a honey containing between 23 and 24% of water.

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By 1926 the experience of handlers of honey indicated that honey of more than 20% of moisture as tested by the hydrometer was in danger of fermentation. Weir (23) expressed this as his experience, and LeMaistre (23) stated that honey reading 42.5° (18.2% at 68° F.) by the Baumé hydrometer was safe from fermentation.

New Zealand has led the way in establishing a high standard for honey. In 1909 Hopkins (11) stated that clover honey of a specific gravity of 1.420 and over was fit for market, and the higher the specific gravity the better. This is equivalent to 17.6% of moisture at room temperature (68.0° F.). The standard of a specific gravity of 1.42 has been adhered to since that time and New Zealand now considers honey of a lower specific gravity than 1.42 as unsafe from fermentation and unfit for export.

Work of the Bee Division, Central Experimental Farm, Ottawa, (unpublished) shows that the average moisture content for Canadian honey is below that set as the standard for New Zealand. Over 1,000 samples, representing all producing areas in Canada for six years, had an average of 16.92% of moisture, the range being 12.7 to 21.0%.

The changing conception as to what constitutes a satisfactory moisture content of honey is also reflected in the change that has been made in the legal definition. In Canada the first "Honey Act" was passed in 1920 and regulations made under the act defined honey as a product containing not more than 25% of moisture. In 1927 the "Honey Act" was included as part of the "Food and Drugs Act" but the regulations were unchanged. In 1931, however, they were amended and the limit for moisture set at 20%. The definition now reads, "Honey shall be entirely the product of the work of bees operating upon the nectar of flowers and other sweet exudations of plants. It shall contain not more than twenty (20) per cent of water, not more than five (5) per cent of sucrose, not more than twenty-five hundredths (0.25) per cent of ash and not less than sixty (60) per cent of invert sugar".

METHODS OF MOISTURE REMOVAL

Evaporation

Before the extensive production of extracted honey came in the "extracted honey era", it was a common practice to store honey in shallow tanks where evaporation could take place from the surface. In 1906 McGregor wrote (14), "I remember when D. A. Jones was 'King' in Canada. He practised and advised extracting before the combs were capped, and ripening the honey in tanks holding 375 pounds. All the beekeepers with whom I was acquainted and I think I may say the majority in Canada followed this plan."

Alexander described tanks (1) which held about 5,000 pounds. He extracted his honey every 6 or 7 days, before it was capped. In this way he said (2) that he received twice the amount of honey and at the same time saved the bees work and saved himself at least half the work in extracting. Root reported (2) that Alexander's buckwheat honey produced in this way was excellent.

Hopkins (10), Government Apiarist for New Zealand, had been sponsoring this method of extracting and ripening honey 23 years previous to the time when Alexander described his method. Hopkins used tanks 20 inches in depth, holding about 2,500 pounds of honey.

During succeeding years, as the "extracted honey era" advanced, the practice of ripening honey in tanks appears to have died out in North America and it has become the custom to leave the honey on the hive until the combs are at least two-thirds capped. This is the accepted standard based on wide experience, yet as Muth (5) is quoted as saying, "The fact of honey being capped is no proof of its being ripened, as we often extract very thin honey from capped cells". Recent experiments (19) have proved the truth of this statement and many beekeepers have found it difficult to produce honey of high grade, particularly in years of heavy rainfall, or in areas of high precipitation. This is especially true of fall honeys.

Ventilating to Ripen Honey

Experimental work in Iowa (16) has shown that special provision for ventilation of the hive is of value to the ripening process when the weather is mild and there is an abundance of nectar, but the temperature, humidity and character of the honey flow are limiting factors. Ventilation, more than that provided by a one-half inch crack, was not accompanied by any increased rate of ripening. In fact, it has been the experience of some beekeepers that extra ventilation increased rather than decreased the moisture content of the honey.

Other Methods of Moisture Removal

Various methods, other than the use of shallow tanks, for removing moisture from the extracted product have been tried, but none has proved to be an outstanding success. One of the most recent methods is by a "dehydration unit", the patent for which was taken out by Préfontaine in 1939 (15). The unit consists of an inverted cone above a vertical cylindrical screen through which heated air is passed. As the honey runs down the sides the hot air passes out through the honey. No report on its use has come to the writer's attention.

Dyment (7) described a set-up which he tried with some success in 1937. It was a steam heated automobile radiator through which air was passed against honey flowing down an inclined plane.

Evaporating Moisture from Honey in the Comb

The hygroscopicity of honey of high specific gravity is such that when it is mixed with honey of a low specific gravity the mixture becomes homogeneous in a very short time. Thus when a comb of honey is extracted, honey from adjacent cells and from all parts of the comb becomes thoroughly mixed. The writer has shown (19) that variation in moisture content occurs from cell to cell, from one part of the comb to another, from side to side and from different combs. This variation was found to be as great as 9.2% in a single comb and 10.7% within a super. As honey is being extracted, thorough mixing results and the product is honey of a uniform moisture content.

If it were possible to remove the excess moisture from the thin honey before extracting, the cause of much low grade honey would be removed. The uncapped cells which usually contain the thinner honey would expose a large surface for evaporation and as the cappings are porous some evaporation might be expected from the capped honey as well. Even capped honey of high moisture content might be improved in quality.

PRINCIPLES OF EVAPORATION AS APPLIED TO HONEY EXPERIMENT

The removal of moisture by air from any substance is dependent upon: (1) the surface area of the substance exposed to the air; (2) the temperature; (3) the relative humidity; and (4) the rate of flow of the air.

Area Exposed

At no time after storing has honey a greater surface exposed than when it is in the comb; therefore, it is at this time that excess moisture can be most easily removed.

Temperature

It is by the application of heat that the temperature is raised to the point where efficient vaporization takes place. It is heat that produces evaporation and not the air, hence the necessity for raising the temperature as high as possible without causing the combs to "melt down." Although the melting point of beeswax is 155° F., combs begin to soften and leak honey at temperatures only slightly over 100° F.

Relative Humidity

Relative humidity is measured most accurately by means of a wet and dry bulb thermometer and a chart from which the results are obtained. In the case of the present investigation, however, a hair hygrometer was used, as it was not possible to use the wet and dry bulb thermometer in the limited space.

Rate of Flow of Air

In the dehydration of fruits it has been found (6) that air velocities above 300 feet per minute and not in excess of 1,000 feet per minute should be used. Eidt reports (8) that in practical operation an air velocity of 800 feet per minute or better has given excellent results in drying of fruit. In order to obtain such a velocity it is necessary to use some sort of fan to force the air between the combs.

Recirculation of air is practised in most dehydrators It is probable that the rate of diffusion of the water through the honey to the surface might be so slow as to permit recirculating a large percentage of the air, thus reducing the amount of heat required.

AN EXPERIMENT TO REMOVE MOISTURE FROM HONEY IN THE COMBS

A review of the literature has failed to reveal any experiments conducted for the removal of moisture from honey in the comb on a practical scale. Consequently the following experiment was outlined for the purpose of determining the possibility of removing moisture from honey in the comb.

Experimental Material and Procedure

Preliminary work included placing a dozen combs in various positions in a dehydrator at the Division of Forage Crops. Later an electric heater was fastened in a box beneath a super containing 4 combs. It was found necessary to install a thermostat to control the temperature, and in order to force the air between the combs a small electric fan was placed in the bottom, beneath the heater.

In order to obtain a rate of flow of air considered efficient with a larger number of supers a motor driven multivane fan was obtained from the Division of Horticulture. At first the trials were made at room temperature, but the necessity for heat was obvious. Electrical heating units were placed in a tunnel in front of the fan so that the ingoing air was heated before being forced between the frames in the supers piled above.

In the final set-up a steam radiator was turned to a horizontal position and enclosed in a box which had a hole the size of a super on top, and a hole in the end where the multivane fan was placed. In this way the air was drawn from the room and forced through the air spaces of the steam heated radiator and upwards through a pile of supers set over the hole in the top.

Check was kept on the temperature range by two maximum and minimum thermometers placed immediately above and below the combs. One thermometer and a hair hygrometer were placed in a super at the bottom of the pile. The instruments could be seen through a glass door. The rates of flow of air were measured by an anemometer at various places just above the interspaces between the combs, and the average rate of flow calculated from these.

The loss in moisture was calculated from the loss in weight of the combs. Individual combs were weighed before being exposed to the desiccating influence in the various set-ups, then at intervals to determine the loss. The moisture content of the honey in some of the combs was calculated by use of the refractometer and Chataway's tables (4) after the evaporation was completed. In the final set-up the moisture content of each comb was taken before and after it was heated. The method was the same as that previously used by the author (19). The following is a summary of the various experiments.

All combs used in I and V were taken directly from supers in the yard.

I. Dehydrator, Division of Forage Crops.
   A. Four Dadant shallow combs hung horizontally.
   B. Four Dadant shallow combs hung vertically with top bars towards the air blast.
   C. Four Dadant shallow combs hung vertically with bottom bars towards the air blast.

II. Four Dadant shallow combs hung in a super above a 500-watt heater—temperature uncontrolled. (Combs began to melt down and leak honey, so results not considered.)

III. In super set above 500-watt heater fitted with temperature control.
   A. Four Dadant shallow combs.
   B. Nine Dadant shallow combs.
   C. Nine Dadant shallow combs.
   D. Nine Langstroth shallow combs.

IV. In super set above a 500-watt heater fitted with temperature control and electric fan.
   A. Nine Langstroth standard combs.
   B. Eight Langstroth standard combs.

V. In super set above multivane fan.
   A. Nine Langstroth standard combs.
   B. Nine Langstroth standard combs, set above A. for last $10\frac{1}{2}$ hours of running.

VI. In super set above multivane fan and using heated air.
   A. Nine Langstroth standard combs which had been sitting in the honey house for 2 weeks.
   B. Nine Langstroth standard combs which had been sitting in the honey house for 2 weeks.
   C. Two supers of nine Langstroth standard combs removed from colonies in the yard.

VII. In supers set above steam heated radiator through which air was forced by a multivane fan.
   Seven supers of nine Langstroth standard combs which had been sitting in a pile with hive covers above and below for four weeks in the honey house.

At first it was thought that loss in weight was entirely from the honey, but on placing a super of dry combs above the supers used in VI. C. during the run it became evident that loss in weight was occurring from the combs and also from the super itself. To determine the loss in weight from dry combs, frames, and supers, four supers of empty combs were set with a super containing frames scraped free of wax and a test made with the set-up used in Trial VI. Loss in weight was determined in each case by weighing before and after the 6-hour run. The following two treatments of the various parts of supers were used in determining loss in weight.

1. Nine Dadant deep frames with wax removed. The combs had been extracted and were recently placed on colonies for cleaning.
2. Four standard Langstroth supers with combs. Number 315 had remained in dry super storage all summer. Numbers 277, 298, and 294 were supers that had been extracted and returned to their respective colonies for one week to be cleaned.

Results

Table 1 shows that losses occurred from the woodwork of supers and from empty combs. Frames scraped clean of wax lost a greater percentage of moisture than combs or supers. A super (315) from dry storage lost less moisture than other supers which had been extracted and returned to the colonies for a week for cleaning.

Table 1.—Loss in weight from empty frames, dry combs, and supers treated at temperature of 91 to 98° F. for six hours for the removal of moisture

Item from super no.	Weight of combs						Loss in weight	
	Before			After				
	lb.	oz.	oz./32	lb.	oz.	oz./32	oz./32	%
Frames	3	14	24	3	14	1	23	1.15
Combs 315	6	1	18	6	1	2	16	0.51
277	10	4	29	10	3	13	48	0.91
298	10	0	30	10	0	7	23	0.45
294	9	0	16	8	15	24	24	0.52
Supers 315	9	1	5	9	0	23	14	0.30
277	7	10	2	7	8	23	43	1.10
298	9	0	27	8	15	18	41	0.89
294	7	13	25	7	12	27	30	0.74

Table 2 shows results obtained when combs of honey were treated in different ways for the removal of moisture.

TABLE 2.—LOSS IN WEIGHT FROM COMBS OF HONEY TREATED AT VARIOUS TEMPERATURES FOR VARYING LENGTHS OF TIME FOR THE REMOVAL OF MOISTURE

Trial		Kind*	Combs	Amount capped	Temp.	R.H.†	Air flow	Loss in weight	H_2O	Hours running
			no.		° F.	%	ft. per min.	%	%	
I	A	D.S.	4	$\frac{3}{4}$	100–110	20–22	400	0.49		5
	B	D.S.	4	$\frac{3}{4}$	100–110	20–22	400	0.61	17.6 (1)‡	5
	C	D.S.	4	$\frac{3}{4}$	100–110	20–22	400	0.51	17.4 (1)	5
III	A	D.S.	4	$\frac{2}{3}$	95–104	25–45	—	0.30	16.6 (2)	6
	B	D.S.	9	Small	95–110	27–40	—	1.32		11
					95–110	27–40	—	1.96	16.5 (1)	24
	C	D.S.	9	All	95–103	42–47	—	0.17		11
					95–103	42–47	—	0.25	15.7 (2)	18
	D	L.S.	9	$\frac{3}{4}$	95–103	40–45	—	0.39		11
					95–103	40–45	—	0.70	17.2 (1)	18
IV	A	L.	9	$\frac{3}{4}$	95–104	43–47	130	0.38		8
					95–104	43–47	130	0.56		13
	B	L.	8	$\frac{3}{4}$	95–104	42–47	130	0.85		19
V	A	L.	9	$\frac{3}{4}$	82–86	31–51	1500	0.09		2
					82–86	31–51	975-1500	0.47		14
	B	L.	9	$\frac{5}{6}$	82–86	31–51	975	0.10		$10\frac{1}{2}$
VI	A	L.	9	$\frac{3}{4}$	93–96	32–38	1500	0.24		2
					93–96	32–38	1500	0.67		6
	B	L.	9	$\frac{3}{4}$	93–96	32–38	1500	0.18		2
					93–96	32–38	1500	0.75		6
	C	L.	9	$\frac{1}{3}$	91–98	25–27	975	0.40		2
					91–98	25–27	975	0.80		6
					91–98	25–27	975	1.40		12
		L.	9	$\frac{3}{4}$	91–98	25–27	975	0.26		2
					91–98	25–27	975	0.69		6
					91–98	25–27	975	1.14		12
VII		Results treated separately in Tables 3 and 4								

*D.S.—Dadant shallow.
L.S.—Langstroth shallow.
L. —Langstroth standard.

† See "Relative humidity of the air" p. 160.
‡ No. in brackets indicates the number of combs on which moisture determination was made by the refractometer after run completed.

In trial I loss was greatest from combs hung vertically with the top bar towards the blast. There was little difference in loss between the combs hung horizontally and those with the top bars away from the blast. The temperature 100° to 110° F. was too high for practical purposes, since combs in trial II "melted down" at this temperature.

In trial III there was little loss from combs fully capped (c), but losses increased as the amount of cappings decreased. Prolongating the time of exposure increased the loss in weight, although the rate of loss diminished with time.

By increasing the rate of flow of air the rate of evaporation was increased in trial IV. Here, too, there was increased evaporation with increased time (A).

Trial V shows that there was little loss in weight at room temperature even with air being forced between the combs.

With heated air forced between the combs the greatest amount of evaporation was obtained in the least time. This is evident from trial VI where supers lost weight according to the condition of the cappings and according to the time exposed, although the rate of evaporation decreased with time.

Results of trial VII are shown in Tables 3 and 4. The average temperature of the air entering the supers after passing through the radiator was 103° F. This temperature had dropped to 97° F. by the time the air had reached the top of the pile of supers. The average rate of flow of the air between the combs was 760 feet per minute. The average relative humidity was 33% as recorded by a hair hygrometer hung in a super at the bottom of the pile.

Table 3.—Loss in weight of honey in combs set above steam heated radiator during two consecutive six-hour periods, at 97° to 103° F.

Rate of air flow 760 ft. per minute. R. H. 33% †

Super No.	Super weight	Area		Loss in weight					
				Six-hour period				Twelve-hour period. Total	
		Of honey	Of cappings	First		Second			
	lb.	%		oz./32	%	oz./32	%	oz./32	%
256	74	95	$\frac{4}{5}$	194	0.59	90	0.27	284	0.87
335	68	80	$\frac{1}{2}$	103	0.41	61	0.24	164	0.65
309	62	90	$\frac{3}{4}$	90	0.32	53	0.19	143	0.52
229	61	90	$\frac{2}{3}$	124	0.46	99	0.39	223	0.85
314	40	65	$\frac{1}{2}$	142	0.94	86	0.57	228	1.52
338	35	75	$\frac{1}{4}$	54	0.47	34	0.30	88	0.77
334	32	50	$\frac{1}{8}$	123	1.27	74	0.76	197	2.03
Totals				830	0.56	497	0.34	1327	0.90

† See "Relative humidity of the air" p. 160.

The seven supers used in trial VII were representative of practically all types that would be taken in the course of harvesting the honey crop. Results in Table 3 are based on the weighings before heating, and after 6 and 12 hours' treatment. It may be observed that loss during the second 6-hour period was only slightly more than half the loss of the first 6 hours.

Refractometer readings made on honey from the combs before and after the 12 hours' treatment give results (Table 4) which indicate twice the loss in moisture that resulted from actual weighings. Thus refractometric methods indicate a loss of 1.8% while the gravimetric methods give a decrease of 0.9% in actual weight.

TABLE 4.—REFRACTOMETRIC DETERMINATIONS OF MOISTURE CONTENT OF HONEY IN COMBS SET ABOVE STEAM HEATED RADIATOR FOR 12 HOURS AT 97° TO 103° F.

Rate of air flow 760 ft. per minute. R. H. 33% †

Super No.	Amount capped	Moisture content						
		Before			After			Loss
		Capped	Un-capped	Weighted average	Capped	Un-capped	Weighted average	
		%	%	%	%	%	%	%
256	4/5	17.6	19.7	17.9	17.3	16.8	17.2	0.7
335	1/2	17.6	20.8	19.0	17.2	14.7	16.2	2.8
309	3/4	16.9	17.2	16.9	16.7	15.3	16.4	0.5
229	2/3	17.6	19.3	18.3	17.4	15.7	16.7	1.6
314	1/2	18.7	21.0	19.6	18.3	15.9	17.3	2.3
338	1/4	15.7	18.5	16.9	15.3	14.2	14.8	2.1
334	1/8	17.7	19.4	19.2	17.1	15.9	16.1	3.1
Average		17.6	19.7	18.3	17.1	16.1	16.5	1.8

† See "Relative humidity of the air" p. 160.

DISCUSSION

At one time it was considered that honey might be extracted from uncapped or only partially capped combs and stored in a ripener for some time in order to evaporate its surplus moisture. However, this practice has been largely discontinued.

Marshall (12) determined that there was no advantage in storing honey of 16.3 to 16.6% of moisture in a ripener for 12 days at 21° C. (69.8° F.). Such honey is of low moisture content and would have a high viscosity which would hinder evaporation. Martin (13) has shown that honey containing 17.4% of water is in equilibrium with the water vapour in an atmosphere of 58% relative humidity, hence honey of 16.3 to 16.6% of moisture would be in equilibrium with a lower percentage relative humidity.

According to Martin (13) the optimum relative humidity for drying honey is apparently somewhere between 0 and 20%. The hair hygrometer used gave readings much too high, so it is probable that the relative humidity was within the optimum range.

Relative Humidity of Air

From meteorological records the hours from 10 a.m. to 6 p.m. for the days when trial VII was conducted had an average temperature of 52° F. with a relative humidity of 53%.

According to Psychrometric tables (9) at 52° F. and 100% R. H. air contains 0.008226 lb. vapour per lb. dry air.

At a R. H. of 53% air would contain $\frac{53}{100}$ of 0.008226 = 0.004360 lb. vapour.

At 103° F. and 100% R. H. air contains 0.04726 lb. vapour per lb. dry air.

Then air heated from 52° F. and 53% R. H. to 103° F. will have a R. H. of $\dfrac{0.004360}{0.04726} = 9.2\%$.

This same air cooled to 97° F. will have a R. H. of $\dfrac{0.004360}{0.03896} = 11.2\%$.

Since the hair hygrometer recorded 33% R. H. for the entering air it is obvious that this was erroneous and that items appearing in column headed "R. H." are too high, but may be used for purposes of comparison.

The relative humidity can be lowered by increasing temperature. Heat not only lowers the relative humidity of the air, but also raises the temperature of the honey and produces evaporation. This has been pointed out in connection with trial V conducted at room temperature. In this trial there were two of the combs which did not lose any weight. Even fully capped combs in trial VI lost weight when heat was applied, although the relative humidity was about the same and the temperature increment only 10° F.

Rate and Amount of Evaporation

When the number of combs in the pile is increased the air friction is increased and the air flows more slowly between the combs. This is brought out in trial V. The rate of air flow through one super of combs was 1,500 feet per minute, but when a second super was added the rate was decreased to 975 feet per minute. However, with 7 supers in a pile, the rate of flow of 760 feet per minute was quite suitable and according to Cruess (6) and Eidt (8) should be efficient.

Although there is a great difference in results in trial VII between weighing, and measuring the moisture content by the refractometer, the latter method has brought out the important fact that uncapped honey, high in moisture content, can be evaporated so that the resulting honey will be well within the limit of first grade. Originally the average moisture content for some combs of uncapped honey ranged as high as 23.1%; after treatment the highest was 17.3%. One comb lost as much as 7.3% of moisture from the uncapped honey. Even the loss of 0.9% by weight was a sufficient amount to raise honey from grade III to grade I had the honey had an original average moisture content of 18.7%.

Uncapped honey invariably lost moisture much faster than capped honey, but with using air of 90° to 100° F. forced between the combs the loss of moisture from capped honey was always measurable.

Amount of Air Required to Carry Heat

Knowing the temperature and relative humidity of the air passing through the supers it is possible to calculate from tables (9, 24) the amount of air necessary to carry the heat required to raise the temperature of the honey to the requisite temperature and evaporate moisture at that temperature.

Specific Heat of Honey

No figures are available for the specific heat of honey, so one has been calculated.

Assume honey to contain 80% of dextrose and levulose and 20% of water. S. H. of dextrose and levulose is 0.275 (24) and that of water is 1.

$0.275 \times 0.80 + 0.20 \times 1 = 0.42.$

Therefore the S. H. of honey is calculated to be 0.42.

Heat required to increase temperature and evaporate moisture

One British thermal unit (1 B.t.u.), the unit in which heat is measured, is required to raise one pound of water one degree Fahrenheit and approximately 1000 B.t.u. are required to evaporate one pound of water.

Temperature of honey (supers, combs, etc.) is raised from 67° (room temperature when starting) to 97° F.

No. B.t.u. required to raise 372 lb. honey from 67° to 97° F. = $372 \times 0.42 \times 30 = 4687.2$.

No. B.t.u. required to evaporate 2.6 lb. water at 97° F. = $1037.5 \times 2.6 = 2697.5$.

Total = $4687.2 + 2697.5 = 7384.7$ B.t.u.

Heat liberated by air cooling from 103° to 97° F.

One lb. dry air at 103° F. contains 24.72 B.t.u.

Vapour to saturate 1 lb. dry air at 103° F. contains 52.25 B.t.u.

At 9.2% saturation vapour contains $\frac{9.2}{100} \times 52.25 = 4.807$B.t.u.

Total $24.72 + 4.807 = 29.527$ B.t.u.

One lb. dry air at 97° contains 23.28 B.t.u.

Vapour to saturate 1 lb. dry air at 97° F. contains 42.97 B.t.u.

At 11.2% saturation vapour contains $\frac{11.2}{100} \times 42.97 = 4.81264$ B.t.u.

Total $23.28 + 4.81264 = 28.09264$ B.t.u.

Difference between heat content at 103° F. and at 97° F. is heat liberated = $29.527 - 28.09264 = 1.43436$ B.t.u.

Weight of air required

7384.7 B.t.u. are required to raise the temperature of the honey and evaporate 2.6 lb. water.

1.43436 B.t.u. are furnished by dropping from 103° to 97° F.

7384.7 B.t.u. are furnished by $\frac{7384.7}{1.43436} = 5148.43$ lb. air.

Volume of air required

One lb. dry air at 103° F. occupies 14.17 cu. ft.

Vapour to saturate 1 lb. dry air at 103° F. occupies 1.08 cu. ft.

At 9.2% saturation vapour occupies $\frac{9.2}{100} \times 1.08 = 0.09936$ cu. ft.

Total = $14.17 + 0.09936 = 14.26936$ cu. ft.

5148.43 lb. air occupies $14.26936 \times 5148.43 = 73464.80$ cu. ft.

Length of time required for air to carry heat

73464.80 cu. ft. of air are required to carry the heat necessary to raise the temperature from 67° to 97° F. and evaporate 2.6 lb. moisture.

Rate of flow of air is 760 feet per min.

No. minutes required = $\frac{73464.80}{760} = 96.67.$

Amount of air required to carry evaporated moisture

It is also possible to calculate the amount of air required to carry away the product of evaporation, in this instance the 2.6 lb. water.

Weight of water vapour per lb. dry air used = 0.004360 lb.

This may be increased to 58% R. H. before evaporation would stop at which time honey would contain 17.4% moisture. Since 17.4% moisture is not far from 17.8% the limit for first grade honey the following calculations have been based on a relative humidity of 50% at 97° F.

Vapour to saturate 1 lb. dry air at 97° F. weighs 0.03896 lb.

At 50% saturation vapour weighs $\frac{50}{100} \times 0.03896 = 0.01948$ lb.

Therefore, air can absorb 0.01948 − 0.004360 = 0.015120 lb. moisture per lb. dry air before leaving at 50% saturation.

Amount of air necessary to absorb 2.6 lb. moisture $= \frac{2.6}{0.01512} = 171.96$ lb. air at 97° F. and 11.2% R. H.

At 103° F. and 9.2% R. H. 1 lb. air occupies 14.26936 cu. ft. 171.96 lb. air occupies 14.26936 × 171.96 = 2453.76 cu. ft.

It is evident that the amount of air required to carry the heat is much greater than the amount of air necessary to carry away the moisture evaporated. The ratio in this experiment is $\frac{73464.80}{2453.76} : \frac{30}{1}$ (approx.).

In the dehydration of fruits the ratio is usually about 7 : 1 (6).

The time required to supply heat necessary for heating the honey and evaporating the moisture, as calculated, is 96.67 minutes or about 1 hr. 37 minutes. Since the total time of heating was 12 hours or more than 7 times the actual length of time required it is clear that a great deal more time is required for honey to yield some of its moisture than for fruits.

CONCLUSIONS

It is possible to raise the grade of honey before extracting by forcing heated air of low relative humidity between the combs. Temperatures must not be much in excess of 100° F. and air velocity of 760 feet per minute has been found to be satisfactory. Recirculation of the air in the room or dehydrator is possible, as the amount of moisture removed from the combs of honey isn't large compared with the capacity of the volume of air passing through the combs. Recirculation is desirable also because the amount of heat required is greatly reduced if it is not necessary to preheat incoming air.

The rate of evaporation from honey in the combs decreases with length of time. Twelve hours has been found to be sufficient time to expose the combs to the blast of heated air, but less time may prove to be the optimum, although the time would vary according to the amount of honey and its moisture content.

Capped as well as uncapped honey lost moisture in the trials recorded.

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VACUUM FUMIGATION FOR INSECT CONTROL[1,2]

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Vacuum fumigation may be defined as a method of accelerating the action of a toxic gas by placing infested material in a chamber from which most or part of the air can be withdrawn before the introduction of the gas. The term "vacuum fumigation" is, strictly speaking, self-contradictory, and as it would be impossible to have "fumes" in a perfect vacuum, the process could be better described as "low pressure fumigation". The expression "vacuum fumigation" is, however, so widely used today that it is undoubtedly here to stay. The technique is used principally in the field of insect control, but could be tested against any form of noxious organism.

Vacuum fumigation is only a little more than a quarter of a century old. It was first used in a practical manner in 1913, simultaneously by E. R. Sasscer and L. A. Hawkins in the United States and D. B. Mackie (3) in the Phillipines. Since that time the process has been thoroughly investigated by workers in different parts of the world. Enough is now known for a few general principles to be defined and for some early popular misconceptions to be corrected.

In common with many applications of chemical and physical science to the field of biology, it is at present both difficult and dangerous to make general statements on this subject. The great differences in the reactions of animals and plants to artificial conditions provide sufficient warning not to attempt to draw too general conclusions from experiments conducted on a particular species in a certain commodity with one or two gases. Unfortunate results are often obtained as the result of the too hasty application of methods, found effective in one set of conditions, to problems where circumstances call for entirely different measures.

Vacuum fumigation is not a separate subject in itself, but is a refinement in the field of fumigation as a whole. The basic principles of fumigation have not been altered by its introduction. It is used whenever special circumstances are encountered which call for increased effectiveness, penetration, or speed.

BASIC THEORY

Fumigation is the ideal method of bringing toxic chemicals into contact with insects, for it is only in the gaseous state that the molecules can safely penetrate and subsequently be ventilated from every space within material which is liable to harbour insects. Ordinary fumigation at atmospheric pressure has the disadvantage that the spaces within the commodity are filled with air and that the process of diffusion, whereby gases tend to distribute themselves evenly throughout the system and to attain equilibrium with the other gases present, is often very slow even when aided by powerful circulating fans.

[1] Contribution No. 19, Division of Plant Protection, Production Service, Dominion Department of Agriculture, Ottawa, Canada.

[2] Unless otherwise indicated by citation in the text, experimental results described in this article are from observations made at the Fumigation Station in Montreal.

[3] Supervising Inspector in charge of Fumigation Station.

FIG. 1.—General view of the Dominion Fumigation and Inspection Station, Montreal, P.Q.

If a large proportion of the air is pumped out of the material and the vault containing it, the fumigant will meet with less obstacles in its path towards the interstices of the commodity, with the result that penetration will be rapid. Here, however, there is one complication caused by adsorption, which in this case, acts as a process of fixation whereby some of the molecules of gas are held on the surface of the commodity and thereby prevented from diffusing any further. It is a highly selective phenomenon, and varies according to both the gas and the commodity used. In vacuum fumigation the absence of the molecules comprising the gases of the air may cause the adsorption of part of the fumigant by the material to be exaggerated, and usually larger doses of fumigant have to be used to allow for this. The degree of adsorption varies inversely with the temperature of the material, hence one of the reasons for requiring warm temperatures during fumigation.

There are two methods of vacuum fumigation commonly practised, the so-called "sustained" and "dissipated" vacuum treatments. In the sustained vacuum, after the removal of the air and the introduction of the fumigant into the vault, no further alteration is made to the pressure during the period of exposure, and atmospheric pressure is not restored within the vault until the time for the "air washing" process. This is now conceded to be the most effective method for fumigating many commodities, but it cannot be applied at low pressures to those plants, fruits, and vegetables which are too delicate to withstand them.

In the "dissipated" vacuum, after the vault is evacuated, the fumigant is introduced either slightly before, or at the same time, that atmospheric air is allowed to flow into the chamber until normal pressure is again reached, or until a very low vacuum, sufficient to ensure closure of the door of the vault, is attained. In this way the pressure during the exposure period is approximately that of the atmosphere. In this technique circulation of the fumigant is usually effected by some system of ducts and fans.

It is now generally admitted that the sustained vacuum method, viewed from the standpoint of insect mortality, is more effective than the dissipated one. It was thought at one time that by introducing the fumigant in a stream of air it could be carried more rapidly into the centre of the commodity. Under some circumstances this might possibly be so, but the introduction of air has the effect of bringing the atmospheric gases into competition with the fumigant for access to the space surrounding the infesting insects. It is true that more rapid penetration is effected than in ordinary atmospheric treatments. But even with the aid of powerful circulation devices, which add to the expense of the equipment, the dissipated method is not as effective as the sustained vacuum with the gases usually employed in fumigation work.

As an illustration of the difference in effectiveness of the three methods of fumigation, some experiments are cited on the toxicity of methyl bromide to bulb mites (*Rhizoglyphus hyacinthi* Boisd.) found inside the leaves of Japanese lily bulbs packed in subsoil in wooden boxes. It was found with 2.5 pounds of methyl bromide per 1000 cubic feet at 60° F. that to obtain complete toxicity to all the active stages of the mites in a sustained vacuum of 1 inch of absolute pressure the exposure period was 2 hours, in vacuum dissipated from 1 inch to atmospheric pressure a period of 3 hours, and in an ordinary atmospheric treatment a period of 4 hours. In this instance the comparative time factors were in the ratios 2 : 3 : 4. With hydrocyanic acid gas and the ethylene oxide-carbon dioxide mixture the difference in the time factor between vacuum and atmospheric treatments is often much greater. Results obtained with 2 to 3 hours under vacuum can sometimes only be repeated by 12 to 24 hours exposure at atmospheric pressure, though in the latter case the doses are sometimes lowered. It must not be assumed, however, that a treatment effective by one method can be applied by rule of thumb to one of the others. For instance, under vacuum hydrocyanic acid gas penetrates bales of broom corn quickly and effectively, but great difficulty was experienced in obtaining complete kills of corn borer larvae in bales at atmospheric pressure, even with increased doses and exposure periods of 24 hours.

Attention is called to the desirability of adopting a uniform method of describing the degree of vacuum obtained in fumigation treatments. At sea level normal atmospheric pressures are in the region of 30 inches of mercury, but the fall in pressure of the atmosphere in gaining altitude is equivalent to approximately 1 inch of mercury for every 1000 feet. Hence at 5000 feet normal pressures would be about 25 inches of mercury. The common practice of calling for a treatment with some such factor as "a 25-inch vacuum" is therefore quite misleading, as in a mountainous location at 5000 feet this might be equivalent to a perfect vacuum. Mercurial

gauges designed to show the absolute pressure in inches of mercury can readily be attached to vacuum vaults. With the aid of these a constant vacuum can be read off irrespective of altitude or outside weather. Hence a schedule calling for a "28-inch vacuum" could be altered to one requiring "2 inches of absolute mercurial pressure" before the introduction of the gas. Uniform pressures could then be obtained every day of the year in any part of the world.

EFFECT ON INSECTS

The highest vacuums produced in fumigating work are in themselves not immediately toxic to most forms of insect life. The killing of the insects by the low pressure is not the principal objective of vacuum fumigation, as many people seem to think. If some insects of different species are placed in a glass flask or jar capable of withstanding low pressures, and the air slowly pumped out, it will be seen that, to begin with, the lowering of the pressure seems to excite the insects and they move restlessly about on the glass surface. Colorado potato beetles will continue to walk up the steep side of a flask at 3 inches of absolute pressure, but at 1 inch they usually fall off. At this stage they may continue to move their antennae and legs for some time. At 1 inch granary weevils seem to move around quite normally. On restoring the atmospheric pressure the insects appear to be none the worse for the equivalent of a rapid trip into the sub-stratosphere.

As a result of comprehensive experiments on the effect of vacuum on a collection of common stored product and household insects, Back and Cotton (1) found that very low pressures in the region of 1 inch of absolute pressure for 24 hours killed all the larvae, pupae and adults of the species used except 50% of the larvae of the dermestid *Trogoderma tarsale*, Melsh, and that 90% of the eggs of the webbing clothes moth survived. At slightly higher pressures, of from 6 to 2 inches absolute in a concrete vault, some insects survived exposures of 4, 5, and 6 days, and after 7 days some larvae of the black carpet beetle, the dark meal worm, and *Trogoderma tarsale* survived. Therefore, although very low pressures are toxic to many insects after a length of time, the vacuums which could be produced and maintained under commercial conditions would take some time to effect complete control, so that the cost of the equipment and length of time required would not justify the employment of this method alone.

Although some insects are very resistant to the effect of low pressures themselves, Moore and Carpenter (4) showed that a gas introduced into a partial vacuum is often more toxic to insects than the same dose released at atmospheric pressure. It is therefore correct to say that exposure to the vacuums produced under commercial conditions (0.5 to 5.0 inches of absolute pressure) will usually make the insects more susceptible to the fumigant.

As has been stated, many of the factors influencing the toxicity of fumigants are common to all methods of fumigation. Other writers have stressed the fact that treatments successful against one stage of the life cycle of a species are not necessarily equally effective against the others. At this time it should be emphasized that wide variations in susceptibility occur between individuals in the same stage of a given species if they are

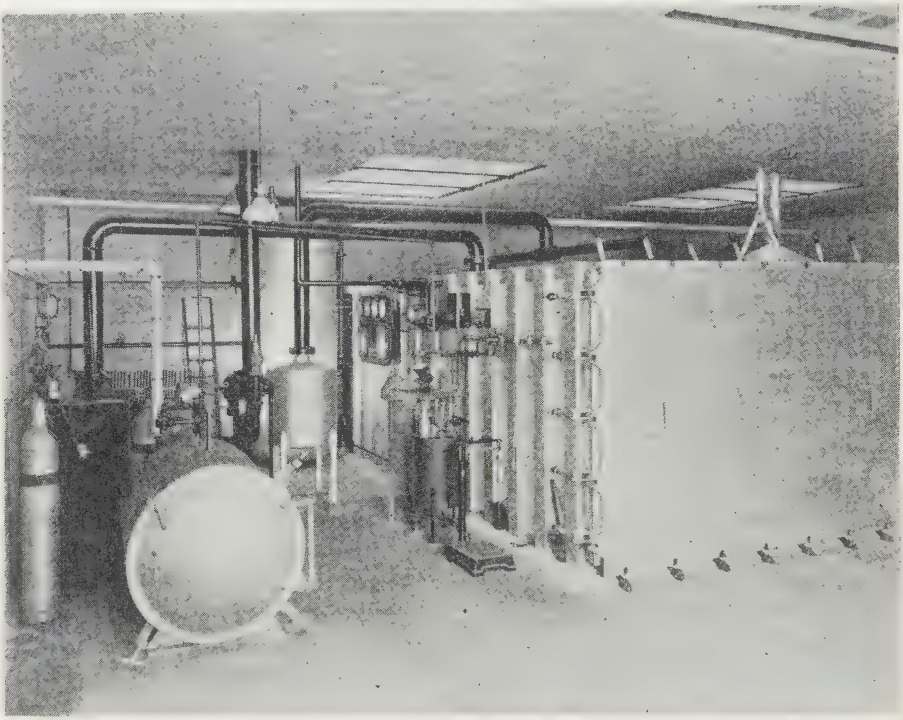

Fig. 2.—Vacuum fumigation equipment with small experimental tank on the left.

at different levels of metabolism. In some experiments it was found in a given population of adult Colorado potato beetles that, during the summer, those which had been starved for one week prior to fumigation were more resistant to methyl bromide fumigation in a dissipated vacuum than those fed continuously until the day before treatment. Furthermore, overwintering adults removed from the soil in September soon after they had completed development were more resistant than summer beetles, but less resistant than their brethren fumigated in January after three months in cold soil and 24 hours of warming at room temperature prior to treatment. In fact, to insure complete kill, the latter collection required twice the dosage found effective against the summer population. At the time of treatment all three groups appeared, superficially, to be in a similar state of activity. In drawing up a dosage recommendation for the complete control of adult potato beetles, therefore, it would be necessary to base it on the treatment which was found to be effective under the most adverse conditions, in this case the one required for the beetles removed from the soil during the winter.

In a given population of an insect species, especially in the immature stages, there are often individuals which are not developing as rapidly as others and which are said to be in a condition of "diapause" or suspended animation. Their metabolic activity (including their respiration) is at a lower level and they are not so susceptible to the effect of fumigants. This fact has been brought out during the fumigation of several species of mature sawfly larvae in cocoons, in which stage they may remain for

periods ranging from a few to many months before pupating. A collection of mature larvae of the European spruce sawfly was divided into two parts, one part being allowed to develop under optimum conditions and the other held in cool storage to retard development. From the first groups some adults emerged from the cocoons and the remainder still in the larval stage were assumed to represent the portion of the population in diapause. It was then found that in vacuum fumigations a higher percentage of the individuals in the diapause collection survived than those in the group representing the original population.

The principle underlying these findings is of great significance in practical work, and may explain the conflicting results sometimes obtained. The important fact is not the apparent activity of the insect at the time of insertion in the fumigation vault, but its history during the preceding days or weeks. A fumigation schedule designed to effect 100% kill of a given insect under all circumstances must take these possibilities into account.

EFFECT ON COMMODITIES

Most "non-perishable" commodities do not suffer from the effects of vacuum fumigation, but care must be exercised in the treatment of many fruits, vegetables and plants. In some cases absolute pressures lower than 10 or 15 inches cannot be employed, or alternatively an initial vacuum of 3 inches of absolute pressure has to be dissipated as soon as possible.

It has been the general impression that one of the advantages of vacuum fumigation is the speedy removal of the residual gases from the commodity by the process known as "air washing". This consists in introducing air at the end of the fumigation period until normal pressure is almost reached, and then the pumping of a fresh vacuum to remove the mixture of gas and air from the vault. This process may sometimes be repeated once or twice before the vault is opened and the workmen are allowed to enter. This technique is doubtless effective for removing gas from the air space in the vault, but is no more effective in this respect than efficient exhaust fans used in many atmospheric vaults. The effectiveness of the air washing process in rapidly removing concentrations of gas from some commodities is not clear. Indeed, in fumigating bales of cotton with hydrocyanic acid gas Johnson, Becker, and Hawkins (2) found that the concentration of hydrocyanic acid gas in the centre of bales of cotton was increased after one air washing and that apparently the only way the gas was removed from the centre of the bale was by the slow process of diffusion.

EQUIPMENT

Vacuum fumigation vaults of all shapes and sizes, equipped with a wide variety of types of vacuum pumps and loading machinery, are found in different parts of the world. It is impossible to lay down any general rules for such installations, as they must vary in design and elaboration according to circumstances. The manufacturers of such equipment will supply full details of installations suited to particular problems. Suffice it to say that an adequate industrial fumigation outfit should be capable of producing 2 inches or better of absolute pressure in not more than 10 minutes, and of maintaining the initial vacuum with but little loss during the fumigation period of 2 or 3 hours.

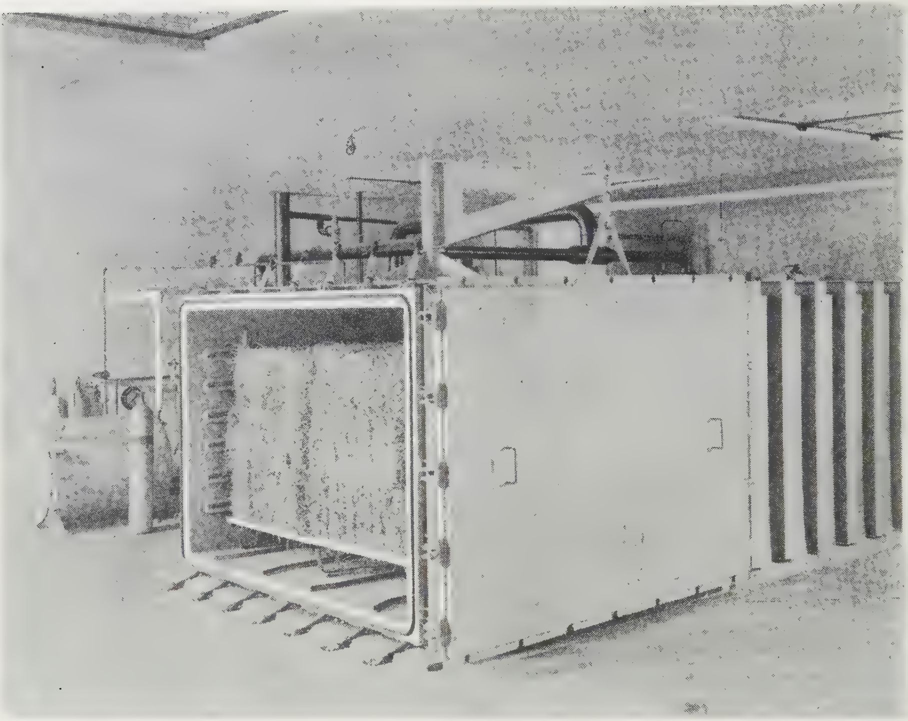

FIG. 3.—Large vacuum fumigation tank.

When installing equipment great attention should be paid to the most rapid method of loading and unloading the vault. A few minutes saved or unnecessary labour reduced will represent large sums of money over a period of years. Some vaults are equipped with doors at each end to expedite simultaneous loading and unloading of goods placed on truck trains. As many commodities are packed in cartons the present trend is towards the construction of rectangular vaults to ensure no wastage of space.

ADVISABILITY OF VACUUM FUMIGATION

Enquiries are received from time to time from firms who have encountered pest problems, regarding the advisability of installing vacuum fumigation equipment. One important feature to consider is the high cost of installation and upkeep as compared with atmospheric installations. Every problem has to be considered separately, particular stress being laid on the amount and value of the goods to be treated from day to day and the difference in time required to secure adequate control in the vacuum and atmospheric treatments. In treatments with methyl bromide this difference does not appear to be as great as with hydrocyanic acid gas and the ethylene oxide-carbon dioxide mixture. But even in the case of a difference of as little as two hours or so, this might represent a considerable factor in the expeditious handling of the goods, and vacuum fumigation could still be adopted with profit.

At present vacuum fumigation is used principally in the milling, prepared food, and tobacco industries, in quarantine work to ensure complete mortality of foreign pests, and to treat furs before they are placed in storage.

RESEARCH PROBLEMS IN VACUUM FUMIGATION

Vacuum fumigation is a comparatively new development in the field of applied science, and there are numerous problems which need solving before further refinements in the technique are made.

The one serious drawback to the successful fumigation of foodstuffs, under vacuum or atmospheric conditions, is that the dead insects are left inside the treated commodities. Indeed, some consumers have expressed the opinion that they "would rather find healthy living insects than dead ones" inside their food. Peas infested with pea weevils, dead or alive, have altogether discouraged some people from eating pea soup. This situation is a great stumbling block to the more general adoption of fumigation, especially for the treatment of recently harvested fruits and vegetables. Perhaps the difficulty could be overcome by physical or chemical means. It may be mentioned that Yagi (5) found that high frequency vibrations could be used to induce fruit fly larvae to crawl out of cherries which they were infesting. The experiment was done on a small scale in a laboratory, and could probably not be applied under practical conditions, but it shows that insects can be forced, by artificial means, to leave their hosts. Would it not be possible to find some agent not immediately toxic to the insects, which could first be applied to make them crawl out before being killed by the poisonous fumigant, applied afterwards? At any rate, the possibility should be very thoroughly investigated before it is too hastily condemned.

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PASTURE STUDIES. XX.

AN ECOLOGICAL AND CROP SURVEY OF STANSTEAD COUNTY[1]

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Pasture study at Macdonald College, added to the research program in 1931 under the title of Pasture Projects, has been concerned with the deteriorated grazings of a district in southern Quebec, the Eastern Townships. Complexity of the problems involved necessitated consideration from several viewpoints: agronomical, chemical, ecological, and nutritional. Efficient restorative treatments can now be recommended from results of agronomical experiments evaluated by methods of ecology and animal nutrition. Chemical studies have explored the interrelationships of phosphorus and potassium with plant and soil.

As the work developed it became apparent that the field experience would be incomplete without knowledge of the status of the pasture resources, types of sward and distribution. Accordingly opportunity was found in 1939 to survey a representative county of the Eastern Townships not only for an estimate of grazings but also to ascertain the general utilization of land. Visualization of the complete agricultural picture was felt essential to show pasturelands in the proper perspective.

Stanstead County, chosen for survey, will be described before introducing methods and results. Although the discussion is confined to natural vegetation and crops for this county as a whole, the extent to which soil types are differently utilized has also been determined and will furnish material for a subsequent paper.

CHARACTERISTICS OF THE AREA SURVEYED

The Eastern Townships of Quebec are situated in the Appalachians and the slope is highly varied. Stanstead County, on the Vermont border east of Lake Memphremagog, has a land area of about 275,000 acres. In this county the altitude ranges from 2,400 feet on Barnston Mountain, granitic intrusion near the American border, to 523 feet, the surface of Lake Massawippi. Barford and Barnston Townships in the southeast have the highest agricultural land averaging possibly 1,300 feet. Farm lands in the balance of the county are 400 to 500 feet lower.

Meteorological records indicate by extremes of temperature that the Townships have a continental climate. Rainfall averages about 40 inches and is well distributed throughout the year with highest precipitation in the warmest month, July. Although mean temperatures and rainfall are not very different from those of the St. Lawrence Lowlands to the north, frost-free days are 40 to 50 fewer in the uplands.

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[1] Contribution from the Macdonald College Pasture Committee. Macdonald College Journal Series No. 156. Representing a portion of the data contained in a Ph.D. thesis presented at McGill University by C. Frankton.

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Under these climatic conditions podsols prevail and this is the only zonal soil type in Stanstead. A preliminary study by McKibbin and Pugsley (21) indicated that soils of the Townships east of Lake Memphremagog, including Stanstead, were more strongly podsolized than those to the west. Cann (3) has carried out a more detailed survey and has mapped the podsolic soil types. His conclusion (unpublished data), that the soils although reworked by glacial action are very closely related to the geological formation, is strongly opposed to the previous theory that the soils were glacier-transported.

The flora of Stanstead and the Townships generally is distinctly more boreal as evidenced by frequency of balsam fir (*Abies balsamea*), white spruce (*Picea glauca*), black spruce (*Picea Mariana*), and the larch, (*Larix laricina*), than that of the lowland. This might be ascribed to the higher elevation making its effect felt through fewer frost-free days but for the fact that on the well-drained soils deciduous woods prevail. Only under edaphically unfavourable conditions for the climax are the softwoods dominant. Recognition of the mixed nature of the woodlands has led plant geographers to concur in considering the region studied as part of a

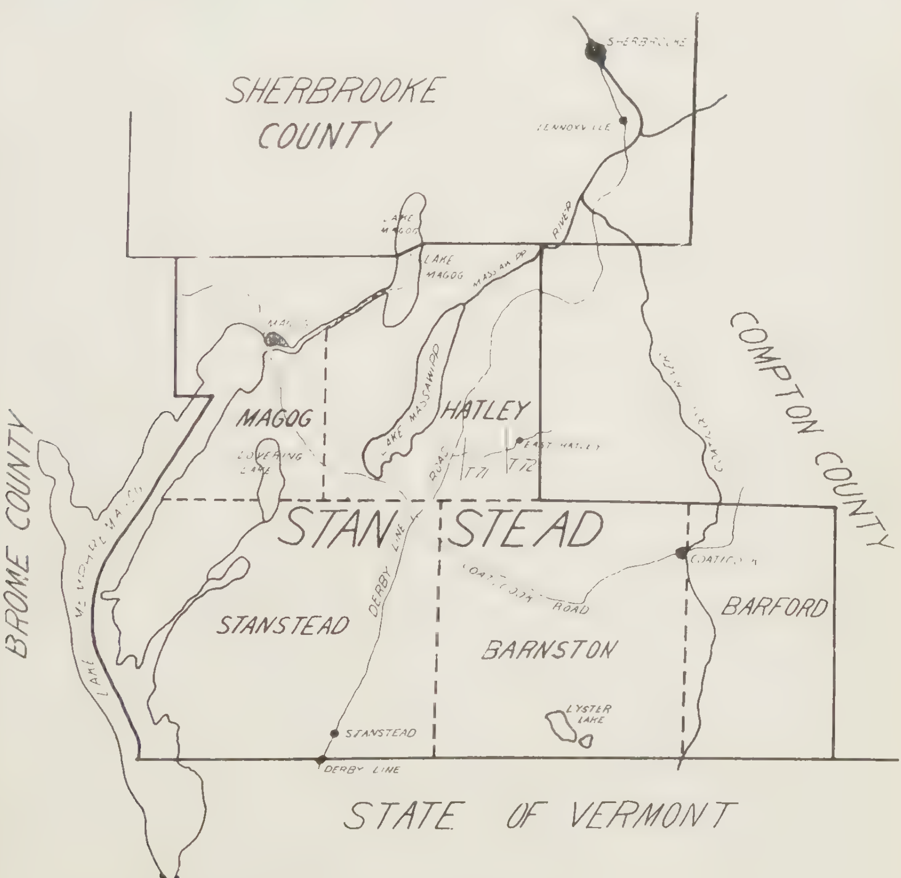

FIGURE 1.—Outline Map of Stanstead County. (Scale is approximately 1 inch to 10 miles.)

forest division lying between the boreal forest, confined almost entirely to Canada, and the deciduous forest of the eastern United States, found only in Canada in the Niagara Peninsula and Southwestern Ontario. Nichols (22) differs from earlier writers in his suggestion that the region is most closely allied to the deciduous forest because of the subordinate rôle of the conifers. Halliday (14) also distinguishes a special Eastern Townships forest section.

For various reasons, hilly topography and a short growing season, the agriculture of the Townships has evolved towards the grasses, grown as hay or pasture, with the principal farm revenue supplied by dairy products and beef. Cattle feed is also responsible for the acreages under oats, barley, corn and roots. Millet, buckwheat, and wheat are only infrequently grown. The woodlots, although fragmentary in comparison with original stands, supply timber for local needs and also pulpwood and telegraph poles to some extent. Maple sugar has been an important industry from the beginning of settlement, and Stanstead still has some of the best maple woods in Quebec.

Difficult of access from the north due to lack of navigable waterways, this region has not had a long history under the plough. Until 1792 the Eastern Townships served as hunting and fishing grounds for the St. Francis Indians. After that date pioneering Vermonters penetrated into the country to be followed by immigrants from the war-impoverished British Isles. Settlements were established in Stanstead County before the close of the eighteenth century at Stanstead Plain, East Hatley and Barnston. Later the numbers of the original settlers were augmented by colonists from the much earlier-settled, and overcrowded, seigneury counties of the St. Lawrence Valley. Agricultural fields rapidly replaced the unbroken forest. Hubbard (17) has depicted the change in his history of Stanstead County, *Forest and Clearing*, where he deplores pioneer recklessness in destroying the standing timber. By 1870 the landscape was probably similar in appearance to to-day's as evidenced by the following quotation, "Instead of an almost boundless forest dotted here and there with small openings, large and well cultivated fields are presented, with very limited reservation of woodland for sugaries and fuel."

The fertility of the soils after forest removal ensured rich grazing and high yields of other farm crops, but in recent years depletion has become increasingly evident. Pasturelands have shown the effects of this depletion to the greatest degree. Years of grazing without replenishment of the used minerals have reduced yields and encouraged the establishment of poorer swards composed of species of lower nutrient values and palatability. At the present time this cycle may be observed on a smaller scale wherever woods are cut and grazing commenced. At first resulting pastures are of excellent quality with Kentucky bluegrass and white clover dominating, but, after varying periods, this sward gives ground to the bents or red fescue and eventually poverty grass. The present survey shows the extent of this pasture deterioration and the condition of forest and areas covered by other crops.

OTHER VEGETATIONAL SURVEYS

Pasturelands have been the subject of ecological surveys in many countries. In our range, Gustafson and Johnstone-Wallace (12) have made

the most intensive investigations. These workers describe the general conditions of grazings in various counties of New York State and give acreages and percentages of the average farm under pasture for different soils. They omit any reference to proportions of the pasture cover under grass and under inedible plants or to the extent of the different swards. Grazing lands of the British Isles have received a remarkable degree of attention as evidenced in Tansley's *The British Islands and Their Vegetation* (27) where work previous to 1939 is summarized. Stapledon's report on Welsh pastures (26) is particularly comprehensive in that all pasturelands of Wales are mapped. Mention should be made of pasture research in South Africa. Deterioration of the fine veldt grazings there has led to an intensive program of pasture work including a preliminary survey of the various kinds of veldt reported by Rowland (24).

SURVEY METHOD

Eastern Township topography and soil variety militate against large-scale farming; a typical farm would consist of about 150 to 200 acres divided into woodlot, pasture, and cultivated fields. The impossibility of mapping a 400-square mile area with such confused intermingling of vegetational types made recourse to line transects, selected at random, essential to the obtaining of a fair estimate of the cover.

Random selection was ensured in the following way. Starting at county boundaries in the case of main highways and at crossroads when using the secondary routes, transects were run at right angles in every two miles from points on the roads chosen by random draw. Care was taken to avoid too close a grouping or intersecting of lines and the result was a reasonably well distributed sampling over the surveyed area.

The procedure is better illustrated by a specific example describing how the position of transect 71 was selected. In this case, a side road from the Derby Line Road, the main highway, was used as a base line. At the intersection of highway and side road the mileage to tenth miles on the mileage indicator of the automobile was noted. A number from 1 to 20, drawn at random, had been inserted previously on each page of the field notebook. This number represented the distance in tenths of miles to be driven before arriving at the site of the transect, and in this instance was four-tenths of a mile. The position of the transect is shown on the outline map (Figure 1).

On arriving at the place selected, compass readings were made to assist in maintaining the right angles, and the two workers separated to left and right. Each continued for one mile noting the different vegetative types encountered. On return, reference was made to the field map and the line of march verified and charted. The various observations recorded were under these headings: (1) pasture: sward dominants, poverty grass, and other pasture herbage, extent of good grass, intensity of grazing and other pertinent facts, (2) woodland: species with dominants, some indication of size whether scrub, bush or forest, (3) hay: presence of red clover or alfalfa, moisture indicators such as sedge or buttercup, (4) grain: whether oats, barley or mixed, any prominent weeds, (5) corn, (6) other cultivated crops, (7) waste land.

Strides were counted throughout the transects and the number required to pass over each vegetative type recorded. In grouping the data, strides were expressed as yards to facilitate comparison with area. The stride lengths of the workers naturally differed and this was taken into account, together with checking possibilities introduced by any points crossed, railroads, roads and streams, that could be measured directly from the map. Department of National Defence maps, scale 1 inch to 1 mile, were used in this survey.

No transects were taken over approximately 40 square miles of stony and hilly terrain, without possibility of agricultural utilization. This unsurveyed territory comprises two sections: The Bunker Hill ridge extending from Fitch Bay along the western shore of Lake Massawippi, and a much larger granitic area of about 30 square miles in the southeast along the Vermont border.

TESTING OF METHODS

Extra transects were made in an 11½-mile triangle in the northeast of the County bounded by Derby Line Road, Compton County and East Hatley Road. Figures obtained compare favourably with those from the original lines particularly with respect to the major crops as shown by the following totals:

Table 1.—Comparison of original and extra transects

(Results expressed as yards)

——	Pasture	Good grass	Grain	Woodland	Hay
Original	4025 (32·8%)	923 (7·5%)	575	4350	2790 (22·8%)
Extra	4280 (34·7%)	895 (7·3%)	720	4270	2645 (21·5%)

This triangle was chosen for a check because in preliminary work all pastures, other than scrub pastures, had been paced off for area, and notes taken on the swards and invading plants and their relative proportions. Making allowances for the scrub pastures encountered on the transects and not on the area survey we find that total acreages and percentage good grass compare very closely by both methods: 26·3% and 5·9% by transect to 23% and 6% by the more inclusive process of seeing all pastures.

RESULTS AND DISCUSSION

General

Yardage figures as first summarized under the main divisions are shown in Table 2.

Individual crops and types of cover will be discussed separately under their headings.

Hay

19·9% of the cover and 75% of all field crops is estimated to be hay. This is not exceptionally high for a dairy region: 84% of the cropland in Berkshire County, Massachusetts, was in hay in 1929, and in Grafton County, New Hampshire, 89% (U.S.D.A. (28)). According to the Canada Year Book (2), hay and clover constituted 60% of the acreage

TABLE 2.—VEGETATIONAL COVER DATA FOR STANSTEAD COUNTY BASED ON MILE TRANSECTS

Cover	Fields	Yardage	Percentage
	No.	Yd.	%
Bush pasture (0 to 9% grass)	176	33,850	11.3
Low grade pasture (10 to 40% grass)	327	60,470	20.2
High grade pasture (over 40% grass)	178	26,865	8.9
Hay	351	59,940	19.9
Grain	140	15,705	5.2
Corn	36	2,350	.8
Other intertilled crops	57	1,780	.6
Scrub	197	33,505	11.2
Bush	195	40,445	13.5
Forest	99	20,880	6.9
Swamp	34	4,445	1.5
	1790	300,235	

under field crops in Quebec in 1938. The larger percentage of hay in Stanstead may be attributed to the conditions for grain being less suitable than in Quebec as a whole.

For varied reasons, length of time under hay, winterkill, and perhaps lack of soil mineral, red clover is rarely heavy. Farmers with poor clover fields recall that their forebears had little difficulty in raising a good stand of clover anywhere on the farm. Introduced seed may be responsible for this but possibly mineral deficiency and increasing acidity of soils under leaching have considerable influence. Frequently hay is grown on fields for long periods without fresh seeding. The result is a cloverless weedy stand with timothy largely replaced by brown top, red top, or red fescue. Winter feed will therefore be low in protein and if cattle are to be kept in good condition expensive purchases of protein feeds are imperative.

Grain

Grain is estimated to be 19% of field crops and 5·2% of the cover whereas Quebec grain acreage in 1938 was 35% of that for all field crops.

Table 3 shows that oats are the dominant grain crop; this compares with the Province as a whole where oats in 1938 had ten times the area of barley. The tendency toward growing oats in such overwhelming proportion is paralleled in other high rainfall countries. Relative to this, Gustafson and Johnstone-Wallace (12), considering New York State, suggest that barley seems to be more demanding than oats and requires a

soil of somewhat higher productivity and lime content. Tansley (27) makes the statement: "Oats mature well in far damper and cooler summers than either wheat or barley."

TABLE 3.—PROPORTIONS OF DIFFERENT GRAINS OBSERVED

Crop	Fields	Yardage
	No.	Yd.
Barley	6	1370
Oats	88	9330
Mixed (barley and oats)	27	3180
Unknown (cut)	21	1735
Buckwheat	1	45
Millet	1	10
Wheat	1	35
	145	15705

Corn

Quebec is not a heavy producer of fodder corn, and husking corn is restricted to a few isolated districts in the St. Lawrence Lowlands. Stanstead, judging by the survey, has $0 \cdot 8\%$ of its area in corn, and the proportion of field crops under corn is $3 \cdot 2\%$, comparing with $0 \cdot 8\%$ of field crops in corn for the Province.

Other intertilled crops

The yardage under this cover is shown in Table 4.

TABLE 4.—AREAS OF OTHER INTERTILLED CROPS

Crop	Fields	Yardage
	No.	Yd.
Potatoes	31	1089
Roots	19	449
Beans	4	42
Mixed	2	110
Cabbage	1	90
	57	1780

This represents only $2 \cdot 3\%$ of the field crops of Stanstead which is rather less than the corresponding figure for Quebec of $3 \cdot 4\%$. Potatoes in Province and County form the larger part of these percentages.

Woodland

Some attempt was made to differentiate woodlots as to size. Scrub constituted the small close wood growth: bush, trees from 2-6 inches: and forest, widely-spaced larger trees. Scrub and bush are far greater in

extent than forest, totalling 24·7% as against 6·9%. Evidently Stanstead woodlots cover about one-third of the farm land this being the average figure estimated by Richards (23) for the five eastern provinces.

Commonest species[1] considering all the soil types are balsam, sugar maple, beech, hemlock, spruce and cedar with an admixture of yellow birch, basswood, ash and red maple. Sugar maple and balsam are the most constant in appearance. Balsam occurs freely on even the well-drained moraine loams.

Weaver and Clements in their text *Plant Ecology* (30) map the area as in the "lake forest" formation. There is certainly no evidence of the "hemlock, white pine, red pine climax" of the "lake forest," and jack pine claimed to be subclimax to the pine-hemlock forest is seemingly not found in this county. Hemlock is common in Stanstead but white pine is rare and red pine probably absent except for an isolated clump at Black Point, Lake Massawippi. These writers mention the possibility of white pine stands having been depleted through lumbering but both Hubbard (17) and Gosse (11), acquainted with the country in pioneer times, speak of the tree as uncommon.

On the other hand, little exception can be taken to Nichols' description, in considering Stanstead flora, that the bulk of the forest consists of hemlock, sugar maple, and beech with admixtures of boreal trees, balsam fir and white spruce. He also mentions white pine as common but generally confined to "pineries" on sandy soil. Red oak considered common throughout is exceedingly infrequent in Stanstead: Gosse was of the opinion in 1840 that no species of oak grew east of Lake Memphremagog. Actually, the red oak was seen twice on this survey and then only as very young growth. All other herbs and shrubs listed by Nichols as characteristic are usual in Stanstead woodlots. Stanstead and the Townships generally can be classed as belonging to Nichols' "hemlock, white pine, northern hardwood region."

Pasture

In the survey, 681 pastures, representing 40·4% of the transect yardage, were traversed. This figure indicates considerable acreages of grazings but compares closely with findings in a dairying county, St. Lawrence, New York State, where pasture ranges from 40% to 50% on the different soil types (Gustafson and Johnstone-Wallace, 13). It is interesting to consider the extent of pasture in some other regions as noted by Holmes (16): Irish Free State, over 67% of the tillable land: United Kingdom, 63%: and New Zealand, 88% of improved land plus an equal

[1] Nomenclature

ash	*Fraxinus* spp.	red oak	*Quercus borealis*
balsam	*Abies balsamea*	red pine	*Pinus resinosa*
basswood	*Tilia americana*	red maple	*Acer rubrum*
beech	*Fagus grandifolia*	sugar maple	*Acer saccharum*
cedar	*Thuja accidentalis*	white pine	*Pinus Strobus*
hemlock	*Tsuga canadensis*	yellow birch	*Betula lutea*
jack pine	*Pinus Banksiana*	spruce	*Picea* spp.

area in native grasses. These countries have a maritime climate ensuring a high carrying capacity for pasture and placing grain at a disadvantage in ripening. The United States with 46% of farms in pasture, Germany 28·5%, and France 38% have a continental climate favouring grain with the added factor in the European countries of an attempt at self-containment.

Herbage estimations from pastures were designed to bring out the amount of grazeable sward as opposed to that which is very low in nutritive value. It is evident from Table 5 that little more than a quarter of the pasture land seen was under a sward composed of better grass species, with the balance, relatively ungrazeable, divided between poverty grass (*Danthonia*) and plants other than poverty grass and the really useful species.

TABLE 5.—BOTANICAL COMPOSITION OF 681 PASTURES

—	Yardage	Percentage of pasture swards	Percentage total cover
	Yd.	%	%
Good grass and clover	33,480	27.6	11.1
Poverty grass	19,425	16.0	6.5
Other pasture plants	68,280	56.4	22.8
	121,185		40.4

Only 48 of the pastures could be considered as open grassland, completely free from plants which indicate ecological progression towards the climax. Good grass occupied the greater part of the terrain on 161 pastures, poverty grass on 113, and other herbage on 407. These three components will be discussed separately.

(a) Grass and Clover

Marie-Victorin (20) records 156 species in Gramineae for Quebec and this list could no doubt be extended.[1] *Festuca capillata* not previously reported from Quebec is established in several sites in the Townships. Although so numerous, few of these grasses are prominent in pastures, and the "sole" of the better pastures is formed of not more than four or five. A typical Kentucky bluegrass sward that supported most of the species found on the better fields is shown as Table 6. It will be noted that all the useful grasses are introduced while the xerophytic "poverty" grasses, poverty grass and panic grass, are native. White clover, as yet, is the only legume important to Quebec graziers.

[1] *Nardus stricta*, an exceptionally rare grass in America, has been found near Weedon Centre, Quebec by Dr. J. H. Whyte, Dore (7). Only other North American records of this plant are: Britten and Brown (1), at Amherst, Mass.; Hitchcock (15), at Waterville, N.H., and Fulton Co., N.Y.; and Farwell (9) in Michigan.

TABLE 6.—SUMMARY OF FIFTY, 10 BY 10 CM. QUADRATS ON A 1000 LINK PLOT

(Estimation by percentage ground-cover)

Species	Common name	Ground covered by species	Origin I—Introduced N—Native
		%	
Useful grasses and clover			
Trifolium repens	white clover	3.9	I
*Agrostis alba**	red top	4.8	I
Festuca rubra	red fescue	3.2	I
Phleum pratense	timothy	1.8	I
Poa pratensis	Kentucky bluegrass	23.2	I
Weed grasses			
Danthonia spicata	poverty grass	.2	N
Panicum lanuginosum	woolly panic grass	.8	N
Bare ground and mosses			
Bare ground		34.8	
Mosses		1.6	
Weeds			
Carex spp. and *Scirpus* spp.	sedges	.3	N
Achillea Millefolium	yarrow	4.8	?
Cerastium vulgatum	mouse ear chickweed	1.6	I
Veronica officinalis	common speedwell	.1	I
Chrysanthemum Leucanthemum	ox-eye daisy	.4	I
Fragaria virginiana	strawberry	1.6	N
Erigeron spp.	fleabane	.2	N
Hieracium aurantiacum	orange hawkweed	2.3	I
Lycopus uniflorus	bugle weed	.3	N
Plantago major	common plantain	.1	?
Prunella vulgaris	heal-all	3.1	N
Ranunculus acris	buttercup	3.0	I
Taraxacum officinale	dandelion	3.6	I
Viola spp.	violet	1.4	N
Hydrocotyle americana	marsh pennywort	.3	N
Oxalis europaea	yellow lady's sorrel	.4	I
Rumex Acetosella	sheep's sorrel	1.4	I
Veronica serpyllifolia	thyme-leaved speedwell	.6	I
Anaphalis margaritacea	pearly everlasting	.2	N

* Syn. *A. stolonifera* var. major. See Malte (19).

Many detailed data have been utilized in preparing a summarized statement for Table 7 showing relative areas of grasses and white clover.

TABLE 7.—SUMMARY OF THE AREAS OCCUPIED BY VARIOUS GRASSES AND WHITE CLOVER

Species	Dominant no. of fields		Corresponding Yardage		Co-dominant no. of fields	Yardage
	No.	%	No.	%	No.	Yd.
Red top and other bent grasses	142	61.5	10,409	61.0	185	13,406
Kentucky bluegrass	18	8	816	4.8	132	9,464
Red fescue	60	26	4,784	28.1	33	8,254
White clover	3	1.3	195	1.4	66	5,017
Timothy	7	3.2	802	4.7	18	1,168

The useful sward species are in order of abundance: red top, red fescue, Kentucky bluegrass, white clover and timothy. Vinall (29) divides the pastures of the United States into five regions determined by climate. Stanstead would be allocated to his "Introduced Pasture Plants Northern Type," north of the 60° isotherm, below which bluegrass, timothy, red top and clover do not thrive. He states that in this region Kentucky bluegrass is the most important pasture plant. Table 7 gives evidence that Kentucky bluegrass is of far less areal prominence than red top or red fescue, at least in Stanstead.

"Mixed" swards containing clover are far richer both in yields of herbage and chemical constituents, particularly in protein (Johnstone-Wallace, 18). Crampton and Forshaw (4) feeding rabbits from pure stands of Kentucky blue and red top have shown that both grasses are unable to support these herbivores for certain periods in the summer, but that red top is generally superior as a single species. Experiments concluded at Macdonald College in 1939 (unpublished) have demonstrated that over a six year period red top has consistently outyielded the bluegrass in all the series of a harvesting test. Red top was as high a producer as timothy and brome grass under the conditions of the experiment. Pure species tests at Ottawa (1936) ranked timothy, red top, Canada blue and Kentucky blue in decreasing order of grass yield.

Considering this information and the fact that red fescue seems to have "nutrient" requirements approaching those of poverty grass it is possible to arrange the various swards observed in the survey in groups of decreasing feeding value (see Table 8). In support of the division of

TABLE 8.—OBSERVED SWARDS ARRANGED IN DECREASING ORDER OF FEEDING VALUE

——	Swards	Yardage	Group total	
			Yd.	%
Group I	Timothy-red top-KB*-white clover	25		
	Red top-KB-white clover	3,638		
	KB-white clover	230		
	Red top-white clover	1,004		
	White clover	195		
	White clover-red top-red fescue	130	5,212	10.5
Group II	Timothy	802		
	Red top-KB	4,266		
	Timothy-red top	1,048		
	Timothy-red top-red fescue	95		
	Red top-KB-red fescue	1,260		
	Red top-red fescue	1,940	9,411	19.0
Group III	Red top	10,409		
	KB	816		
	KB-red fescue	45		
	Red fescue	4,784	16,054	32.4
Group IV	Poverty grass	18,875	18,875	38.1

KB—Kentucky bluegrass.

Group II from Group III it was rather arbitrarily assumed that fields with more than one important grass have a wider range of nutritional possibilities and consequently greater feed-value. Also evidence of smaller yields from single species plots than from any of the mixtures either of grasses or grasses and legumes was obtained by Eisele and Aikman (8). Timothy, however, by virtue of high palatability and yield should be ranked only slightly below the clover swards.

It is obvious from Table 8 that Stanstead swards are largely composed of inferior single species or mixtures without white clover. However, experimental data from field plots (Frankton, 10) makes it apparent that adequate surface manuring will change the poorest swards to the most nutritious, containing clover.

(b) Poverty grass

Notes taken in the field differentiated between poverty grass and poverty grass-weedy swards, but as far as grazing purposes are concerned both types are of equal value. Only in rare cases are either grazed after the early part of the year; 12,611 yards of poverty grass and 6,264 of poverty grass-weedy were seen in the survey.

Poverty grass, from Table 5, covers 16% of the pastures observed which leads to the estimate of 6·5% of total cover in the County. The plant appears on most fields to some extent but the purest stands are in the northeast on the Compton County border where a strip of fields nearly five miles long is completely yellow with the uneaten and matured herbage in late summer.

These poor pastures have a still more limited grass and weed flora than those of higher value (Table 6), poverty grass frequently being undisputedly dominant over large acreages. Table 9 gives an example of this type of field. The appearance of white clover on this pasture is exceptional,

TABLE 9.—A TYPICAL POVERTY GRASS PASTURE

(Ten 6-inch quadrats—basal ground-cover method—in percentage)

Quadrat Numbers		1	2	3	4	5	6	7	8	9	10
SPECIES	COMMON NAMES	%	%	%	%	%	%	%	%	%	%
Trifolium repens	White clover				5						
Agrostis alba	Red top			[1]	15						
Danthonia spicata	Poverty grass	40	35	40	30	35	40	50	50	40	30
Mosses		10	5			5	5				
Bare Ground		45	50	55	50	55	55	45	45	50	65
Achillea Millefolium	Yarrow					[1]	5			[1]	
Fragaria virginiana	Strawberry		[1]		[1]					[1]	
Hieracium aurantiacum	Orange hawkweed	5	5	[1]	[1]	[1]			5	5	5
Lycopus uniflorus	Bugleweed	[1]	[1]	[1]	[1]	[1]		[1]		[1]	
Oenothera perennis	Sun-drops		[1]								
Potentilla simplex	Cinquefoil					[1]			[1]		
Antennaria sp.	Pussy-toes					[1]	[1]	[1]			[1]
Total *Danthonia* and bare ground		85	85	95	80	90	95	95	95	90	95

[1] = present.

for 100 extra throws with the 6-inch quadrat disclosed only one white clover plant and 6 of hop clover (*Trifolium agrarium*), and of course, 93 without clover.

(c) Other Pasture Plants

Plants other than poverty grass or the better sward species were estimated to be in control on 56% of the line transects passing through pastures. Table 10 indicates in condensed form the major elements constituting this portion of the pasture cover. Little grazing is furnished by these plants and their presence obviously reduces the ground that would be held by the edible herbs.

Eradication of these unwanted species is difficult and exclusion practically impossible unless the grazing is carefully controlled. Natural vegetation, formed by, and more exactly adapted to the environment, tends to return at the slightest lessening of the inhibiting factor. That good management is rare is indicated by the fact that only 7% of the pastures seen were open sward without invaders. Close grazing in our humid region with its forest climax is always essential to prevent initiation of the succession leading towards a normal climax.

Sedges and their allies dominate over large portions of the pasture fields (Table 10) and this is chiefly on the undrained and perhaps economically undrainable soils. Forest removal by reducing transpiration increased ground moisture and the result is wet, virtually ungrazeable, ground. The stage in succession between sedges and woody plants is

TABLE 10.—PREVALENCE OF PASTURE PLANTS OTHER THAN POVERTY GRASS AND THE BETTER SWARD SPECIES

Dominant plants	Yards	Percentage
	Yd.	%
Hardhack	6,609	9.8
Hardhack and other species	8,313	12.3
Ferns	5,388	8.0
Goldenrod	1,707	2.5
Buttercup	2,803	4.2
Conifers	11,450	17.0
Deciduous	5,371	8.0
Sedges and sedge allies	18,402	27.3
Other species	7,377	10.9
Total	67,420	—

evidently protracted as the forest is only slowly returning. In these swales grazing is negligible and reforestation is indicated. Hardhack and the tall herbaceous species belong to the succession taking place on the drier soils. Removal of these plants would permit the grazing area to be extended readily, particularly if intensity of grazing were increased and fertilization effected.

DISCUSSION

Information has been obtained relative to the present use of land in Stanstead County and, indirectly, by means of the cover, to the extent of soil depletion and mismanagement. Fertility can be judged to a fair degree by the cover, particularly of old pastures. Davies (6) stresses the importance of vegetation as illustrative of soil fertility and also gives point to careful sward investigation in an ecological survey: "The herbage cover growing on land that has been down to pasture for a long term of years is probably the best measure we have of the status of the soil fertility of that land."

Further grouping of the different categories of plant cover arranged under Table 2 discloses that in Stanstead pastureland comprises 40·4%, tilled land and hay 26·5%, and woodland and swamp, 33·1%. This does not give a true indication of the amount of land used in agriculture unless that portion of pasture acreage composed of innutritious species, poverty grass and such plants as hardhack be deducted from pasture. After this correction it appears the terrain supporting agriculturally useful plants is approximately 37·6% (tilled land and hay 26·5%; good grass on pastures 11·1%).

Limited attention was directed to the quality of crops other than pasture, though it was noted that hay, quite generally, was weedy and had a low proportion of red clover. More can be said about the quality of grazing, as pastures received most consideration during the survey. Only 27·6% of the grazing observed was covered by forage plants. A comparative figure from New Jersey (Sprague-25), where 50% to 70% of the pasture area is occupied by forage plants, is a good measure of the extent to which grazing value of the Eastern Townships has been reduced. Rich "mixed swards" containing clover are far less common than swards composed chiefly of single grasses or mixtures of grasses. Red top is the most extensively spread herbage plant, while Kentucky bluegrass, supposed to be the more demanding grass, controls a smaller area. Red fescue, tolerant of relatively low fertility conditions, is widespread. It is interesting to consider the relative occurrence of these species in New Jersey where Kentucky bluegrass is more prominent, by far, than red top, and red fescue is seemingly absent. Poverty grass was approximately 4% of the cover in New Jersey and 16% in Stanstead.

Undoubtedly large acreages of grazing would respond to treatment; their improvement would lead to the possibility of far more grazing animals being carried. Plot experiments in Stanstead County illustrate how fertility can be restored by surface fertilization leading to considerable betterment in the swards and yields. Grazing trials with steers (Crampton and Raymond (5)) have shown that fertilization can be made profitable by increases in steer weights and carrying capacity over those on unfertilized fields. It would be unwise, however, for a farmer to improve a large part of his pasture without increasing the stock or curtailing the area open to grazing. On most pastures present stocking would be too light for prevention of succession invasion if the whole area were fertilized. It would

be far better to improve a smaller area on which grazing would be sufficiently intense to prevent entrance of scrub and either to return the balance to woodland or bring it into the cropping acreage.

The unbroken forest of the early nineteenth century has been replaced by a diversified cover of agricultural fields intermingled with patches of immature and inferior woodlands. Poor as these remaining woodlots are, depletion is still continuing through cutting and the practice of allowing the stock to forage through the woods. Few farmers, unfortunately, realize that their woodlots should be treated with the same care as other farm crops if adequate revenue is to be expected. Richards (23) stresses the undesirability of pasturing woodland and describes how proper management will increase productivity without at any time requiring clear-cutting of the stand. Forest cover could be augmented considerably by permitting much of the unimprovable land now classed as pasture to return to wood: such fields are those supporting sedges, frequently on undrained and economically undrainable soil types, and grasslands in rocky situations. Poor forage would be replaced by valuable forest growth. Also restoration of fertility, greater retention of rainfall and reduction of leaching would result on these areas.

SUMMARY

1. No authoritative estimation of vegetational cover exists for any area of County size in the Eastern Townships or even in Quebec Province. The survey reported permits the vegetational cover of Stanstead County to be presented. The problem of estimating the different types of cover in this county led to the development of the transect method. This is described and tests of its efficiency given.

2. According to the method of estimation, pastureland in Stanstead comprised 40·4% of the cover, tilled land and hay 26·5%, and woodland and swamp 33·1%. Agriculturally useful plants are present on 37·6% of the terrain (tilled land and hay 26·5%; good grass on pasture 11·1%).

3. The different crops and woodland are discussed. Forest was found to cover only 6·9% of the County although smaller trees and scrub totalled 24·7%.

4. The pasture cover, from 681 pastures, is further divided to show proportions under good grass and clover, poverty grass and other pasture plants. The good grasses and clover are slightly over a quarter of the pasture area.

5. Vinall (29) suggested that, in the northeastern states and presumably in adjacent Canada, Kentucky bluegrass was the most important pasture plant. This survey finds red top and red fescue to be far more abundant than the bluegrass.

6. The good grass and clover fraction is divided to show the relative areas of the different grasses and white clover. Red top is the most abundant grass. White clover is rarely important.

7. The different grass and clover swards appearing in the transects are arranged in decreasing order of feeding-value. It is shown that Stanstead pastures are largely composed of inferior single species or mixtures without white clover.

8. Nichols (22) classes the Eastern Townships ecologically as "hemlock, white pine, northern hardwood" but Weaver and Clements (30) map the region as in the "lake forest" climax. Nichols' contention is supported by these observations of flora in Stanstead County.

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THE EFFECT OF AMMONIUM PHOSPHATE ON THE YIELD AND QUALITY OF LINSEED FLAX IN NORTHERN SASKATCHEWAN AND NORTH-EASTERN ALBERTA[1]

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In the past decade, considerable attention has been given to experimental work with fertilizers for wheat on prairie soils. Where moisture was not a limiting factor, the fertilizer, particularly phosphates, not only showed increased yields but hastened maturity and gave added strength in fighting weeds and rootrots. Improved methods of application and the production of high analysis fertilizers are two important changes in the use of commercial fertilizers which are considered to have added to their success.

PREVIOUS WORK

Many investigations have been conducted on the effect of fertilizers on the growth of the flax plant for fibre. The early work in this field was reviewed by Robinson and Cook (6). The results showed that increased yields might be obtained by the cautious use of nitrogenous fertilizers, especially in combination with other elements. Phosphate was considered less effective than potash and nitrogen. Few experiments have been carried out on the effect of fertilizers on linseed flax on different soil types in the field. Most of these have been conducted in other countries where soil types are different.

In Germany, an experiment was conducted with different fertilizers, including nitrogen, potash, and phosphate in different combinations plus lime, in four different climatic regions (3). Most plots in this instance responded to nitrogen, the highest yield of seed resulting from the use of nitrogen and potash. Seed from plots which did not receive nitrogen had a higher fat content and a lower nitrogen content. Climate appeared to have a general influence on the increase in iodine number. Low temperature produces high iodine numbers and vice versa. Low precipitation conditions were also effective. The action of nutrients on the increase in iodine number became effective with warm climates with low precipitation. Schmalfuss (7) in a later study used increasing amounts of nitrogen and also of lime. Increasing the rate of nitrogen application gave increased yields of seed, a slight lowering of the fat content, and a considerable decrease in iodine number and drying ability of the oil. Similar results were found with increased rates of application of lime.

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In India (1), with a linseed type of flax, a reduction in yield of seed resulted from the use of superphosphate, but no remarkable effect was shown on the percentage of oil content.

MATERIAL AND METHODS

In this experiment two varieties of flax, Bison and Redwing, have been used. Bison is a large-seeded vigorous-growing variety of medium late maturity. Redwing is a small-seeded type with strong straw, maturing in some instances a week or more before Bison.

These varieties were seeded in plots of 4 rod rows, each spaced 9 inches apart and replicated 4 times. The test was sown on summer-fallow land. The fertilizer used was ammonium phosphate containing 11% of nitrogen and 48% of available phosphoric acid. A preliminary test was conducted at a number of Illustration and Sub-stations in 1937 using an application of 30 lb. of fertilizer per acre. The fertilizer at this rate of application appeared to have reduced the germination of the flax at a number of points so that in the succeeding two years the rate was reduced to approximately 20 lb. per acre and good stands were obtained. The number of points at which tests were located was increased considerably in 1938, and again in 1939.

The location of these tests covered a wide territory, including one of the main centres of flax production in the prairie provinces. Flax at present is grown principally in the brown soils zone, cereal crop zone 1 B and the dark brown soils zone, zone 2 B and 2 D. Cereal crop zones are based on climatic factors in addition to soil types and zones 3 D, 3 E, 4 A and 4 B are also represented in this experiment.

The moisture conditions in the crop year of 1938 were somewhat better at most points than that for the two years previous and were considerably improved in 1939. The spring of 1938 had fair to good growing conditions over most of this area and growth had a healthy appearance. Later in the season moisture became deficient, particularly in the north, and some locations in zone 3 E and 4 B suffered. In 1939, moisture in the early part of the season was slightly above normal and satisfactory stands were obtained. However, in some locations drought again became a factor later in the season and yields were somewhat affected.

RESULTS

Effect on Yield

The yield per acre in bushels is given in Table 1 for both varieties and both years of this test. Averages are given for the main soil zones and the soil texture at each location indicated. It will be noted that good yields have been obtained on the black soils zone as well as on the brown soil zone which is at present a centre of flax production. Fairly satisfactory yields were also obtained on soils of lighter texture although many consider the flax crop suitable only to the heavier soil types.

TABLE 1.—FLAX FERTILIZER TRIALS, 1938-1939

Yield per acre in bushels

Cereal Variety Zone	Location	Texture	Bison				Redwing			
			Check		Fertilized		Check		Fertilized	
			1938	1939	1938	1939	1938	1939	1938	1939
	Brown Soil Zone:									
1B	Dunblane, Sask.	Loam	4.7	14.4	6.2	17.1	3.9	20.8	6.4	24.0
1B	Loverna, Sask.	Silty clay loam	3.3	5.7	4.6	5.6	3.3	6.9	4.4	5.9
1B	Kindersley, Sask.	Clay		10.3		9.8		9.3		8.0
		Average	4.0	10.1	5.4	10.8	3.6	12.3	5.4	12.6
	Dark brown soil zone:									
2B	Guernsey, Sask.	Fine sandy loam	5.5	35.4	8.2	41.1	8.3	34.8	7.7	46.8
2	Juniata, Sask.	Fine sandy loam	10.1	5.5	9.8	7.0	8.4	7.1	9.4	9.3
2B	Rosetown, Sask.	Silty clay loam	25.1	16.5	27.8	16.4	22.5	12.5	24.6	17.8
2D	Chauvin, Alta.	Silty brown loam	12.9	3.2	16.3	3.5	12.6	4.1	14.7	4.8
2D	Consort, Alta.	Loam	12.4	5.2	13.5	8.9	10.9	7.4	12.7	9.9
		Average	13.2	13.2	15.1	15.4	12.5	13.2	13.8	17.7
	Black soil zone:									
3D	Birch Hills, Sask.	Silty clay loam		19.8		21.8		19.6		20.2
3E	Meota, Sask.	Fine sandy and light loam		9.3		10.3		12.2		13.9
3E	Hafford, Sask.	Loam	4.6	16.6	4.8	15.7	4.8	16.4	4.8	16.5
3E	Rosthern, Sask.	Loam and light loam		19.0		28.5		31.1		31.5
4A	Paddockwood, Sask.	Loam	19.0	11.0	17.6	9.2	16.8	14.4	19.3	17.5
4B	Meadow Lake, Sask.	Silt loam	13.9	10.1	13.6	11.6	13.7	13.3	12.9	16.7
4B	St. Paul, Alta.	Light clay loam	20.1	11.0	20.5	9.0	15.6	12.6	18.4	10.8
		Average	14.4	13.8	14.1	15.2	12.7	17.1	13.9	18.2
	Degraded black soil zone:									
3D	Tisdale, Sask.	Silty clay loam	18.8	30.3	18.0	30.8	17.3	30.4	16.5	32.2
3E	Parkside, Sask.	Fine sandy loam	9.1	18.2	6.4	15.4	6.9	20.7	7.1	15.6
4A	Lens, Sask.	Heavy loam	19.8	25.6	26.1	29.0	20.3	30.7	24.5	29.4
4A	Chelan, Sask.	Fine sandy loam	14.9	16.0	18.9	19.6	20.9	23.7	22.2	21.9
4A	White Fox, Sask.	Light and fine sandy loam	20.8	24.5	22.8	29.1	19.9	33.6	23.2	26.3
		Average	16.7	22.9	18.4	24.8	17.1	27.8	18.7	25.1
	Grey soil zone:									
4B	Glenbush, Sask.	Loam	5.1	8.2	4.7	7.4	5.8	10.2	6.3	10.2
4B	Glaslyn, Sask.	Loan	5.9	5.6	6.6	8.6	7.8	10.0	8.0	9.2
4B	Pierceland, Sask.	Fine sandy loam	6.5	4.6	6.6	2.7	6.6	3.4	5.7	3.8
		Average	5.8	6.1	6.0	6.2	6.7	7.9	6.7	7.7

The yields of those locations having tests in both 1938 and 1939 have been summarized in an analysis of variance in Table 2. It will be noted that, though the differences between fertilized and unfertilized plots are small, they are highly significant. The varieties were chosen because they were distinctly different in many respects. It is not surprising, therefore, to find that differences between the yields of these varieties, the several

Table 2.—Analysis of variance of the yield of flax varieties for the years 1938 and 1939

Source of variation	D.F.	S.S.	M.S.	F value
Total	151	11,565.17		
Between treatments	1	40.75	40.75	16.30†
Between stations	18	6,950.71	386.16	154.46†
Between varieties	1	37.90	37.90	15.16†
Between years	1	367.35	367.35	146.96†
Between treatments × stations	18	96.39	5.36	2.14*
Between treatments × varieties	1	.04	.04	.00
Between treatments × years	1	.35	.35	.00
Between varieties × stations	18	91.21	5.07	2.03*
Between varieties × years	1	61.52	61.52	24.60†
Between years × stations	18	3,716.79	206.49	
Error	73	182.16	2.50	

Note.—* Significant at 5% level.
† Significant at 1% level.

points tested, and the years are all highly significant. There is no interaction between treatments and either varieties or years so that we may conclude that the influence of the fertilizer was independent of these two factors. The interaction between treatments and stations is significant but not highly significant. The fertilizer treatment therefore may be more beneficial on some soil types than others. On examination of the data, it will be noted that these differences are somewhat erratic, but increases are higher and more general on the dark brown and the brown soil zone.

Table 3.—Mean oil content and iodine number for fertilized and untreated varieties of flax, 1937 to 1939

	Bison		Redwing	
	Check	Fertilized	Check	Fertilized
Oil Content				
1937	42.01 ± 0.21	42.00 ± 0.22	40.84 ± 0.24	40.80 ± 0.14
1938	42.05 ± 1.06	41.92 ± 0.28	40.61 ± 1.12	40.22 ± 0.32
1939	41.93 ± 0.29	42.27 ± 0.32	40.45 ± 0.27	40.54 ± 0.30
Iodine Number				
1937	186.94 ± 4.11	188.18 ± 5.02	192.74 ± 3.19	191.23 ± 3.25
1938	189.44 ± 3.10	189.01 ± 4.02	194.24 ± 2.31	194.64 ± 2.09
1939	185.64 ± 4.15	185.62 ± 3.21	192.32 ± 2.14	193.56 ± 2.20

Effect on the Quality of Seed

Samples from fertilized and unfertilized plots were sent to the Grain Research Laboratory, Winnipeg, Man., in each of three years for analysis of oil content and iodine number. In each year 9 samples were analysed.

These were chosen to represent the whole area, but the same stations were not all analysed in successive years. The mean values and standard error of the mean for oil content and iodine number are given in Table 3. It will be noted that Bison is higher in oil content than Redwing but lower in iodine number. The oil content has not varied from year to year but the iodine number is higher in 1938 than in the other two years.

The use of ammonium phosphate appeared to have no effect on either the oil content or iodine number in relation to variety or the location in which the test was applied. Previous studies (5) have indicated that varieties have inherent differences with regard to oil content and iodine number. Surveys of the flax from the Prairie Provinces (4) have been made showing that environmental factors, principally precipitation and soil type, have a considerable effect on the quality of the flaxseed, more particularly on the iodine value of the expressed oil. These differences are shown very clearly in the variance of oil content and iodine number for these three years in Table 4, in which only variation for stations and varieties show significance.

TABLE 4.—VARIANCE OF OIL CONTENT AND IODINE NUMBER OF SAMPLES FROM FERTILIZED AND UNTREATED PLOTS OF BISON AND REDWING, 1937 TO 1939

Source of Variation	D.F.	Variance		
		1937	1938	1939
Oil Content				
Treatments	1	.054	.614	.410
Varieties	1	13.573†	22.247†	23.200†
Stations	8	.9796†	3.844†	1.094†
Treatments × varieties	1	.001	.147	.160
Treatments × stations	8	.0347	.178	.045
Varieties × stations	8	.2961†	.418*	.399*
Error	8	.0449	.117	.082
Iodine Number				
Treatments	1	.1746	.002	.111
Varieties	1	176.446†	244.922†	417.521†
Stations	8	64.193†	33.012†	38.899†
Treatments × varieties	1	4.011	.837	.747
Treatments × stations	8	16.947	1.562	.160
Varieties × stations	8	3.706	3.901	4.768†
Error	8	4.203	2.173	.619

NOTE.—* Significant at 5% level.
† Significant at 1% level.

DISCUSSION

In discussing the fertilizer requirements in the northern prairie belt, Ellis (2) found a marked response to phosphate. Applications of phosphate on flax land, in general, have not given profitable returns. On the other hand, several investigators have reported increased growth with the use of nitrogen fertilizers especially when used along with other elements. In this experiment no check plots were used to determine whether nitrogen or phosphate alone might give an increased yield. Under the conditions of this test, both may have been effective. Increases appear to be a little

more consistant on the brown and dark brown soil types. However, it is known that in the grey soils particularly, a response to legumes and applications of sulphur results where moisture is reasonably plentiful. The effect of other fertilizer treatments on the flax crop should warrant further investigation.

The belief still prevails in some quarters that flax rapidly depletes the soil of plant food elements. If flax were a heavy feeder even light applications of fertilizer, especially on soils that might tend to be deficient in some elements, might be expected to increase the yield appreciably. In this experiment the increases in seed yield tend to be small, so that applications of fertilizers might be more profitable on crops other than flax. However, the increase becomes significant when considered on a percentage basis. Considering the low rate of application, and hence low cost per acre, any soil which responds favourably to applications of ammonium phosphate on wheat or other crops should be worthy of a trial with flax.

SUMMARY

The application of 20 lb. of ammonium phosphate with 2 varieties of flax has been tested at different points in northern Saskatchewan and northeastern Alberta for two years.

Significant increases in the yield of seed have resulted in general from this practice. There is some indication that this treatment may have benefited some stations more than others, though the data are not conclusive. Heavy applications of ammonium phosphate, 11-48-0, may injure the germination of flax.

No effect has been shown on the quality of the seed as indicated by analyses of the oil content and iodine number.

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MANGANESE DEFICIENCY IN SOILS AND CROPS

1. CONTROL IN OATS BY SPRAYING; STUDIES OF THE RÔLE OF SOIL MICRO-ORGANISMS[1]

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Oats and barley would not grow to normal maturity within a localized area on a field at the Ontario Agricultural College. This area is fairly sharply defined from neighbouring soil by being darker in colour and somewhat of a muck nature. One could predict to within inches the border line to which oats and barley would develop normally. Except for a higher organic content, soil analysis revealed no abnormality with respect to pH or content of readily soluble major nutrient elements. Investigations were conducted during 1940 to determine if deficiency of certain of the minor elements might be the cause of the disorder. Oats were used for experimentation.

INVESTIGATIONS

1. *Field Experiments*

Oats that had been sown on the soil in question began to show symptoms of chlorosis and stunting on June 1, which was about one month after seeding. Plots within this area were sprayed with $\frac{1}{4}$, $\frac{1}{2}$, 1 and 2% aqueous solutions of borax, zinc sulphate, iron sulphate and manganese sulphate, respectively. Ten days later, all plots sprayed with manganese had resumed the normal green colour and soon showed marked increase in growth rate. No response was obtained from the applications of the other three elements.

It was then assumed that there was a manganese deficiency. Accordingly, plots were laid out to test the relative efficiencies of soil and spray applications of manganese sulphate, also to determine the number of spray applications necessary to develop oats to normal maturity. Because it was late in the season, early-maturing oats (Alaska) were used for experimentation.

Five rows of oats, each 4 rods in length, constituted a test plot. For soil applications, manganese sulphate ($MnSO_4.4H_2O$) diluted with fine quartz sand was drilled into the rows prior to seeding at the rates of 140 lb. and 280 lb. per acre, respectively. For foliar application, a 1% aqueous solution of the manganese sulphate was used. In one instance bentonite clay ($\frac{1}{2}$%) and soap (1 ounce per gallon) were added as a sticker and spreader. The number and time intervals of spray applications are given in Table 1.

A temporary response to soil applications of manganese was observed. One month after seeding the check plots exhibited typical chlorosis and stunting. The plots that obtained manganese were sharply defined by normal dark green foliage and better growth. However, the apparent response soon began to fade. Within a week the plot that had received

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manganese sulphate at the rate of 140 lb. per acre could scarcely be distinguished from the check plots, and on harvesting no significant increase in yield of either straw or grain was obtained (Table 1). The plot that received twice as much manganese sulphate exhibited a visible response for about 2 weeks' time, after which it appeared little better than the check plots. Nevertheless, as may be seen in Table 1, the yield of straw and grain was approximately double that of the check.

Spray applications of manganese proved to be more efficient than soil applications. Within 10 days after spray application, all evidence of chlorosis had disappeared and thenceforth growth was much more rapid than in the check plots; Plate 1, Figure 1, illustrates the colour contrast

TABLE 1.—DATA ON INCREASE IN YIELD OF ALASKA OATS BY THE APPLICATION OF MANGANESE

Treatment	Times of application in weeks from seeding	Av. weight of above-ground parts*	Av. weight of grain	Grain weight as percentage of above-ground parts
		lb. per acre	bu. per acre	%
Spray application:				
1% $MnSO_4$ + Bentonite + Soap	4 weeks	5,069.8	35.03	23.6
1% $MnSO_4$	4 weeks	4,354.4	34.32	20.4
1% $MnSO_4$	4 and 6 weeks	5,582.9	32.03	19.6
1% $MnSO_4$	4, 6 and 8 weeks	5,458.5	35.48	22.0
1% $MnSO_4$	4 and 8 weeks	4,821.0	31.73	23.2
Soil application:				
140 lb. $MnSO_4$ per acre	In drills on date of seeding	1,399.7	5.15	12.2
280 lb. $MnSO_4$ per acre	In drills on date of seeding	2,068.3	11.73	19.1
Check	—	1,102.2	5.73	17.3
Significant difference in per cent (5% point)	—	8.47	14.35	—

* Yield data obtained from the experimental plots were recalculated on an acreage basis.

that was evident in sprayed and check plots. At the time of reaping the sprayed plants were about 1 foot taller than the checks. Plate 1, Figures 2, 3 and 4, give evidence of the response as seen at harvesting from a single spray application of 1% manganese sulphate applied 1 month after seeding. The data given in Table 1 indicate the increase obtained in yield of both straw and grain. The late planting (June 10) and a very heavy rust infection were primarily responsible for a maximum yield of only 35 bushels

PLATE I.

Response obtained after a single foliar spray of 1% $MnSO_4$, applied 1 month after seeding of oats on a manganese-deficient soil.

FIGURE 1. The dark strips represent the sprayed rows; these had resumed a normal green colour. The lighter coloured areas represent the check plots which exhibited chlorosis. Photograph taken 10 days after spraying.

FIGURE 2. Sheaves obtained from 30 linear feet of sprayed (left) and check (right) plot rows.

FIGURE 3. Panicles from sprayed (left) and check (right) plants.

FIGURE 4. The grain from single panicles of sprayed (left) and check (right) plants.

1.

2.

PLATE II.

Petri-plate preparations (explanation in text) to illustrate the activity of manganese-precipitating bacteria in manganese-deficient and in normal soil, respectively. Photographs taken after the plates had been incubated at 25° C. for one week.

FIGURE 1. Manganese sulphate diffused from the central disc portion into the soil-agar complex where the bacteria converted the manganese into the oxide form resulting in a dark brown ring. From the black spots in this ring manganese-precipitating bacteria were isolated.

FIGURE 2. The same process was evident but much less extensive when the adjoining normal soil was used in the Petri-plate preparation.

per acre. It is apparent that a single spray, with spreader and sticker added, is just as efficient as repeated sprayings. To all appearances this single spray eliminated any evidence of manganese deficiency.

2. *Biological Phenomena Contributing to Manganese Deficiency*

Gerretsen (3) found that, in sterile manganese-deficient culture media (quartz sand, water culture) healthy oats can be grown with a very low manganese content (5 to 10 p.p.m.). Therefore failure, in the present work, to obtain adequate response from the soil applications of manganese sulphate probably indicated that most of the manganese was being rapidly converted into a form unavailable to the plants.

It is known that manganese can be present in the soil as both soluble and insoluble compounds. The active participation of the soil microflora in the conversion of manganese from soluble to insoluble forms has also been established (Beijerinck (2), Söhngen (6), Gerretsen (3), Mulder (4) and Waksman (8). Soil micro-organisms may play an indirect rôle in the conversion of soluble manganese compounds to insoluble oxides in that they are able to form oxacids with various kinds of plant materials; the oxacids catalyze manganese oxidation. Also reported are soil micro-organisms that utilize the energy released by direct manganese oxidation.

The possibility that soil bacteria are a factor in the instance of manganese deficiency herein reported was investigated. The technique of Gerretsen (3) for the isolation of manganese-precipitating bacteria was followed. Thirty grams of the black soil[1] was agitated with 25 c.c. of distilled water. This mixture was added to quickly-cooled 2% agar and poured in Petri plates. After solidification, a hole, 2 cm. in diameter, was cut in the centre of the soil-agar complex and filled with a suspension of washed quartz sand and agar containing 1% $MnSO_4.4H_2O$. After 1 week's incubation at 25° C. a brown precipitation ring developed (Plate 2, Figure 1) similar to that described by Gerretsen. Dispersed through this ring were numerous dark brown spots which Gerretsen has described as colonies of manganese-precipitating bacteria. The formation of this precipitation ring was prevented by subjecting the plates to a temperature of 0° C., but on returning the plates to 25° C. the ring developed. Addition of Diversol (a bactericide) to the soil-agar complex also prevented the formation of the ring.

When the normal red soil was substituted for the black soil in the aforementioned experiment, a less pronounced precipitation ring developed (Plate 2, Figure 2). This ring was slower in development and contained fewer and smaller brown spots. The Spurway test (7) for water-soluble manganese indicated 5 to 10 p.p.m. within the precipitation ring when the red soil was used and 2 to 5 p.p.m. when the black soil was used. This test was made when the precipitation ring was at maximum density. At that time the central disc portion of each plate contained 10 p.p.m. of water-soluble manganese.

Bacteria were isolated from the dark brown spots within the precipitation rings. These soil colonies were transferred to dilution blanks, agitated, and used to inoculate plates containing Gerretsen's medium (containing

[1] For the sake of convenience, the soil with apparent deficiency of available manganese will be referred to as the "black" soil; the normal soil will be referred to as the "red" soil.

2% calcium citrate, 0.2% ammonium sulphate, 0.5% manganese sulphate and a trace of magnesium ammonium phosphate, homogeneously suspended). After 1 week's incubation at 25° C. a large, brownish-black, metallic type of colony predominated in nearly all the plates; they were not as numerous when obtained from the red soil preparation as from the black soil. Retransfer of these colonies to Gerretsen's medium resulted in the same type of colony; transfer to beef agar slopes resulted in colonies of a milky-white colour.

The aforementioned bacterial isolates from both types of soil were tested for ability to convert manganese sulphate to an unavailable form *in vitro*. Gerretsen's medium for isolation of manganese-precipitating bacteria (described above) was dispensed in broth form in tubes and autoclaved. The ammonium sulphate was sterilized separately. These tubes were inoculated with the isolates, incubated at 25° C. for 8 days, then tests made for water-soluble manganese (Spurway (7)) every 4 days until the cultures were 36 days old.

Nineteen isolates from the black soil were used. Of these, 8 maintained a constant level of 10 p.p.m. of available manganese, similar to the control tubes; 3 exhibited a reduction to 5 to 10 p.p.m.; 4 a reduction to 2 to 5 p.p.m., and 4 a reduction to 1 to 2 p.p.m. of available manganese. Eleven isolates from the red soil were used. Of these, 6 maintained a constant level of 10 p.p.m. of available manganese, similar to the control tubes; 3 exhibited a reduction to 5 to 10 p.p.m., and 2 a reduction to 2 to 5 p.p.m. of available manganese. It was of interest to note that some of the cultures showed an increase in available manganese after they were about 30 days old; accumulation of metabolic products may have been a factor. Those isolates most active in manganese conversion characteristically presented a dark brown to blackish-brown and metallic type of colony. The bacteria were Gram negative medium-sized rods.

Four of the aforementioned cultures, containing isolates which were the most active in manganese conversion, were tested, qualitatively, for the presence of manganese dioxide. The contents of each tube were filtered and washed 7 times with distilled water to remove the soluble manganese. The residue was then agitated in a beaker containing 2 gms. of lead dioxide, 5 c.c. of dilute nitric acid, and 14 c.c. of distilled water. A distinct violet colour was obtained in all four instances, indicating the presence of manganese dioxide.

DISCUSSION

No abiotic factors were found which might influence the level of available manganese in the black manganese-deficient soil and in the neighbouring red soil where oats grow normally. The possible exception to this might be the higher organic content of the black soil. The investigations indicate, however, that the soil flora is of major significance. Cultural experiments have shown that the black soil contains bacteria capable of rapidly converting soluble manganese compounds to the insoluble oxides. The minor response obtained from soil applications of manganese sulphate at such rates as 280 pounds per acre also indicates that the conversion to an unavailable form is relatively rapid. A lesser

number of a similar type of manganese-oxidizing bacteria was found, culturally, to be present in the neighbouring red soil. Preliminary soil tests have shown that the acid soluble manganese is considerably lower in the black than in the red soil. The pH of the black soil is 7.5 and the red soil 7 to 7.5. According to Gerretsen (3) these values are within the range for the active participation of bacteria in manganese oxidation.

Soil micro-organisms may also reduce manganese. Waksman (8) states that manganic compounds may be reduced to manganous compounds by biological processes. Gerretsen (3) states that oats expressing manganese deficiency may recover after a prolonged rainy period. He explains this by the water content of the soil being raised to such a degree that microbiological reduction processes become possible; as a result sufficient manganese is brought into solution to bring the plants back to a healthy condition. Gerretsen's observations were substantiated in the present instance. Previous attempts (1929, 1932, 1935 and 1936) to grow oats on this black soil resulted in plants which ceased growth when about 6 weeks old and produced no grain. The growing season of 1940 was abnormally wet and the manganese-deficiency symptoms were less evident than in the previous years; at least some grain was obtained as indicated in Table 1.

It is possible, then that the red soil maintains a balance of soil microflora whereby sufficient manganese is available for the normal development of oats. On the other hand, the black soil contains an excess of bacteria, and possibly other micro flora, capable of, or contributing to, manganese oxidation, thus reducing the level of available manganese below the minimum requirements for the normal development of oats.

Gerretsen (3) claims that the grey speck disease[1] of oats is not caused by manganese deficiency alone; the appearance of typical symptoms depends, in addition, on the presence of certain bacteria which attack the roots of the plants. He found that in a number of cases the ammonia content of manganese-deficient plants proved to be 2 to 3 times that of normal plants, this being partly due to ammonia produced by micro-organisms attacking the root-tips, partly also to protoplasmic autolysis following extreme carbohydrate hunger caused by reduced photosynthesis. He states further that these alkaline products, especially those transported by the sap-stream from the roots into the leaves, appear to be responsible for the typical leaf spots of the grey speck disease. The typical symptoms of grey speck (greyish necrotic areas on the leaves) were observed by the writer but Gerretsen's explanation of the cause on the basis of root injury does not seem to apply in this instance. A foliar spray application of manganese sulphate eliminated any evidence of chlorosis and completely prevented any further development of the necrotic areas. If, then, ammonia or other decomposition products are responsible for the necrosis it must have been produced by protoplasmic autolysis within the leaves alone.

Although spray applications to grain may be considered a new approach to maintenance of mineral nutrition, in this particular instance it is economically practicable. A single spray application of 1% manganese sulphate plus a sticker and spreader apparently eliminated all evidence of manganese

[1] The progressive development of symptoms of manganese deficiency of oats is described by Gerretsen (3) and Samuel and Piper (5). A recent publication (1) illustrates typical symptoms in natural colour.

deficiency. This spray can be applied about one month after seeding when little damge to the plants would occur. The cost of materials would not exceed $1.50 per acre.

It would seem unnatural that the instance of manganese deficiency herein reported is singular in occurrence in Ontario. The prevalence of such remains to be investigated. Studies will also be made of the tolerance of other crops to a low level of available manganese. The soil in question affords an excellent opportunity for such a study under natural conditions. Peas growing on the same type of soil beside the plot used for investigation showed some chlorosis. A single spray application of 1% manganese sulphate resulted in their return to normal colour within a week's time.

Spraying as a means of detecting deficiency of such trace elements as manganese has possibilities. The technique is simple and the response obtained with oats was outstanding. Where applicable it would eliminate the difficulties attendant on the determination of the available amounts of such trace elements by soil analysis.

SUMMARY

The cause of abnormal development of oats within a localized area on a field at the Ontario Agricultural College was found to be manganese deficiency. This was initially detected by spraying sample areas of chlorotic oats with aqueous solutions of various trace elements among which was manganese sulphate. Alaska oats were sown and used for further experimentation.

Soil applications of manganese sulphate gave only minor response. A single spray application of 1% manganese sulphate, with bentonite and soap added as sticker and spreader, apparently eliminated all evidence of manganese deficiency. This application was made about one month after seeding when the plants were 8 to 10 inches high and just beginning to show some chlorosis. Response was observed 10 days after spraying.

The cause of manganese deficiency in the soil in question is apparently biological. Bacteria were isolated which actively converted manganese sulphate to the oxide form *in vitro*. It seems evident that this soil contains an excess of bacteria, and possibly other micro-organisms, capable of, or contributing to, manganese oxidation, thus reducing the level of available manganese below the minimum requirements for the normal development of oats.

Bacteria, capable of oxidizing manganese, were also isolated from neighbouring soil on which oats grow normally. They were, however, fewer in number than was found in the manganese-deficient soil. It is likely that this soil maintains a balance of the soil micro flora whereby sufficient manganese is available for the normal development of oats.

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BOOK REVIEW

"The Second Yearbook of Research and Statistical Methodology" by Oscar Krisen Buros; 383 pages. The Gryphon Press, Highland Park, New Jersey (Price $5.00).

Every research worker in agriculture as well as in other fields of science must follow some plan in conducting his research investigations. Few, if any, of the results of research can be presented without the use of some statistical procedure. The research worker who is making the greatest contribution is the one who knows best how to plan his work and present his findings in the most satisfactory manner, and he must, therefore, be constantly on the lookout for literature which will assist him in these two objectives. He must know what is correct and up-to-date and what is erroneous and outmoded. Teachers, students and librarians are constantly buying and using books. What shall I buy and what shall I use is the ever present problem. Before they can buy a book intelligently and use it with the best results they should know what competent reviewers think of that book, what are its weaknesses and what are its strong points; one review is usually not enough because there are frequently marked differences of opinion in the appraisals of reviewers of any particular book.

No one can read all the books that are written on any particular subject and few, if any, have time to search the periodicals to see what reviewers think about each new book. In the field of research and statistical methodology such tasks are now unnecessary because Dr. Buros has put in his *Second Yearbook* an invaluable compilation of critical reviews of all the recent books published in English on this subject.

The *Second Yearbook* contains 1,652 review excerpts from 283 journals. The books reviewed include a wide variety of subjects—agriculture, accountancy, actuarial mathematics, biology, botany, business, economics, eugenics, forestry, general science, mathematics, medicine, philosophy, physics, political science, public health, sociology and statistics.

The book is unique, it is timely and it is a fine contribution to the needs of all those, including editors, reviewers and writers, who have any interest in research and statistics in many fields of scientific endeavour.

—W. C. Hopper.